Canadian Technical Report of Fisheries and Aquatic Sciences No. 1550

July 1987

A History of Canadian Fisheries Research in the Georges Area of the Northwestern Atlantic

by

R.G. Halliday, F.D. McCracken,[1]

A.W.H. Needler,[2] and R.W. Trites[3]

Fisheries and Oceans
Scotia-Fundy Region
Biological Sciences Branch
Marine Fish Division
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth
Nova Scotia, B2Y 4A2

[1] Deceased

[2] Box 481, St. Andrews, New Brunswick

[3] Physical and Chemical Sciences Branch, Coastal Oceanography, Bedford Institute of Oceanography

89-05355/

PREFACE

This document was first produced to serve as a background paper during Canadian preparations for the International Court of Justice case concerning delimitation of the maritime boundary in the Gulf of Maine Area. It was completed in typescript form in 1982 just prior to the death of Frank D. McCracken and represents his last scientific contribution. This account reflects many aspects of his extensive career contributions to fisheries science in this Region, and serves as a small tribute to his memory.

Minister of Supply and Services Canada 1987

Cat. No. Fs 97-6/1550E ISSN 0706-6457

Correct citation for this publication:

Halliday, R.G., F.D. McCracken, A.W.H. Needler, and R.W. Trites. 1987. A history of Canadian fisheries research in the Georges Bank area of the Northwest Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1550: iv + 37 p.

TABLE OF CONTENTS

Page

Preface ii

Abstract/Resumé iv

Figure 1. Gulf of Maine Area showing geographic features mentioned in text 1

Introduction 2

Groundfish 3

Pelagic Fish 7
- Small Pelagic Fish 7
- Large Pelagic Fish 10

Invertebrates 12
- Sea Scallops 12
- Lobsters 14
- Red Crab 15
- Squid 15

Oceanography 16

Concluding Remarks 17

Acknowledgements 17

Selected Bibliography 18

Appendices

1. Research reports related to NAFO Subareas 5 and 6 matters published by Canadian research workers 18
2. Record of Canadian fisheries research vessel activity in NAFO Subareas 5 and 6 (including charters) 26
3. Record of Canadian fisheries research vessel activity south of NAFO Subarea 6 32
4. Record of Canadian observers aboard domestic commercial fishing vessels for the purpose of collecting biological data - NAFO Subareas 5 and 6 33
5. Record of physical oceanographic observations made from Canadian vessels in Subarea 5 36

ABSTRACT

Halliday, R.G., F.D. McCracken, A.W.H. Needler, and R.W. Trites. 1987. A history of Canadian fisheries research in the Georges Bank area of the Northwestern Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1550: iv + 37 p.

The nature and extent of the Canadian fisheries research presence on Georges Bank up to 1980 is documented. Lists are given of research cruises, commercial vessel trips on which biological observers were aboard, physical oceanographic observations made by Canadian vessels, and of research reports which published the results of work by Canadians relevant to the fishery resources of the area.

The Gulf of Maine Area (NAFO Division 4X + Subarea 5) has been the area in which the major Canadian research effort on scallops, herring, and large pelagic fishes has focussed and much of it has been on Georges Bank, particularly for scallops. Groundfish research efforts concentrated in more easterly areas, as did the Canadian groundfish fishery, but research on Georges Bank resources was commensurate with fishing interests.

RESUMÉ

Halliday, R.G., F.D. McCracken, A.W.H. Needler, and R.W. Trites. 1987. A history of Canadian fisheries research in the Georges Bank area of the Northwestern Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 1550: iv + 37 p.

On documente la nature et l'importance de la participation canadienne à la recherche halieutique dans le banc de Georges jusqu'en 1980. On présente des listes énumérant différentes activités: campagnes de recherche, sorties de navires commerciaux ayant des observateurs à bord, observations en océanographie physique réalisées par des navires canadiens, rapports de recherches publiés sur les ressources halieutiques de cette région et qui sont le fruit du travail de Canadiens.

Le Canada a entrepris un effort de recherche très important sur les pétoncles, le hareng et les grands poissons pélagiques dans la région du golfe du Maine (division 4X et sous-zone 5 de l'OPANO); une bonne partie de cet effort a porté sur le banc de Georges, surtout en ce qui concerne les pétoncles. Dans le cas des poissons de fond, l'effort de recherche a porté principalement sur les régions situées plus à l'est, là où se trouvent les zones de pêche canadiennes pour le poisson de fond, mais l'effort de recherche sur les ressources du banc de Georges a été proportionnel aux intérêts du point de vue de la pêche.

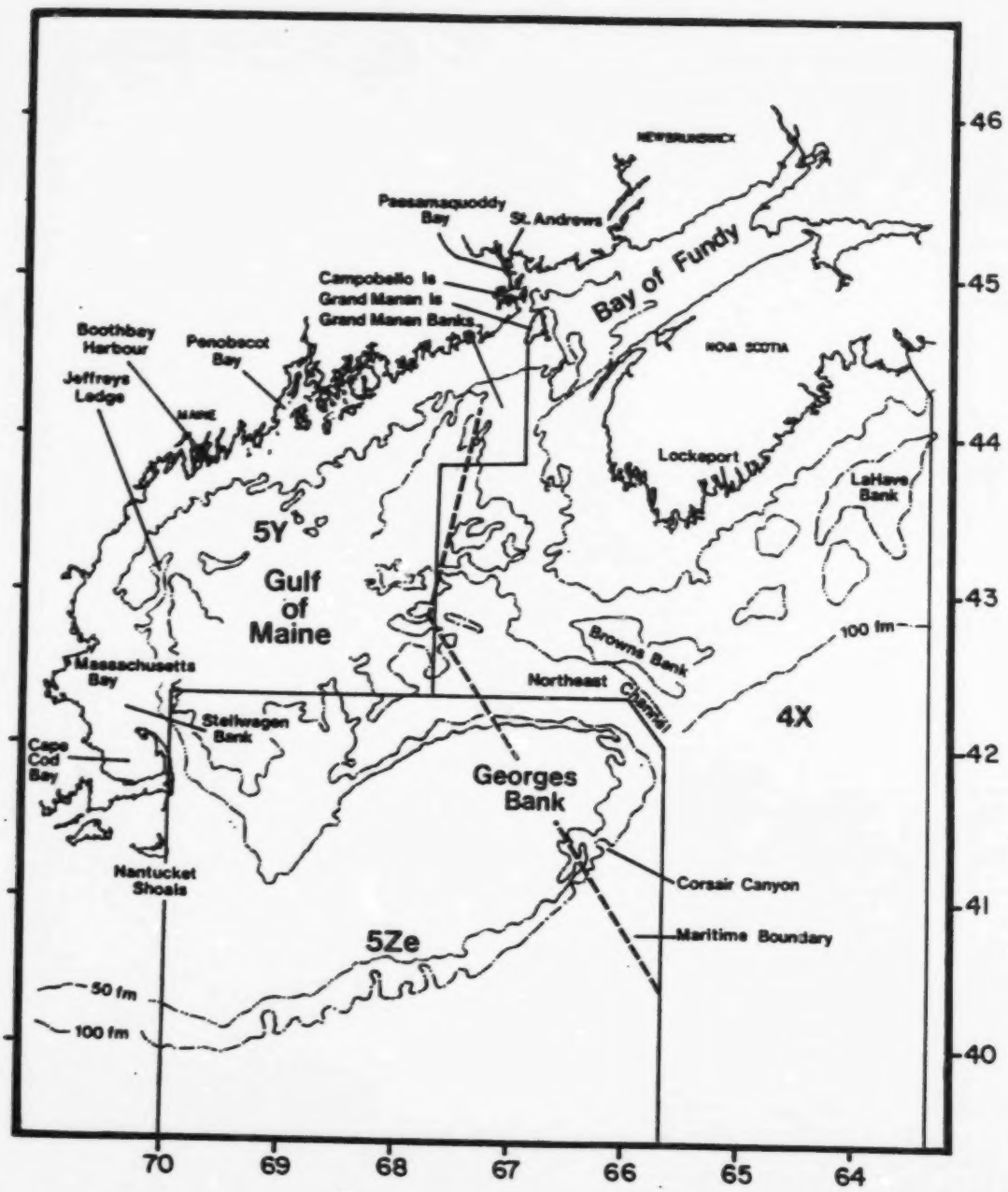

Figure 1. Gulf of Maine Area showing geographic features mentioned in the text.

Introduction

The purpose of this report is to document the nature and extent of the Canadian fisheries research presence on Georges Bank (Fig. 1) from its beginning until 1980. While stocks of some species such as sea scallops form units associated with Georges Bank alone, and research directed at them is clearly research on Georges Bank, other resources, such as swordfish, are much more wide ranging, although an important component of the resource, and the fishery, have occurred on Georges Bank. This introduces an element of subjectivity as to what should be included in this report. As a general rule a fairly strict approach has been taken and most of what is included here relates to studies based on observations made on Georges Bank. Exceptions fall into three categories. Work to the south of Georges Bank on squid and large pelagic fishes is included not only because these resources support important fisheries on Georges Bank but also to illustrate the range of Canadian operations to the south in what became USA waters in 1977, and beyond into the Caribbean and Sargasso seas. Also included are some aspects of research in areas adjacent to Georges Bank in the Northwest Atlantic Fisheries Organization (NAFO) Subarea 5 and Div. 4X. The research included, although physically off Georges Bank, involves aspects which relate to understanding the biology of resources in a wider area which includes Georges Bank; herring tagging and larval distribution studies provide good examples. Thirdly, research conducted in other areas for which one of the motivations was the application of the results to Georges Bank fisheries is also included. It is quite clear, for example, that studies of the performance of the "offshore" scallop dredge, although conducted in the southern Gulf of St. Lawrence, were conducted there because the area provided suitable conditions for scuba diving. The intention, however, was to utilize the results in an analysis of the Georges Bank scallop fishery, the primary fishery in which this type of dredge was utilized. In summary, we have interpreted presence to include influence, and tried to document the impact of Canadian scientific efforts on the fishery for and management of, resources of the Georges Bank area.

The research reported here is almost entirely research funded by, and conducted by staff of, the Government of Canada. This reflects the lack of research on offshore fisheries resources by Canadian universities and provincial governments. The early history of marine fisheries research in Atlantic Canada is the history of the Atlantic Biological Station at St. Andrews, New Brunswick. The first fifty years of this history is well documented by Hart (1958). He gives the full time professional staff levels for various years as follows:

Year	1924	1930	1936	1942	1948	1954
Staff	2	6	9	9	12	24

These numbers, combined with the descriptions of available research vessels, are explanation enough for a limited presence in any of the offshore areas prior to the 1950's. Amalgamation of the Newfoundland Biological Station in St. John's with the Fisheries Research Board of Canada, at the time of Newfoundland's confederation in 1949, substantially augmented the federal research presence on the Atlantic coast. With this, however, came increased responsibilities and most of the Newfoundland based research efforts were expended in the Labrador-Grand Bank area. The squid research expeditions, mounted from St. John's to the southern waters of Georges Bank and south, are notable exceptions. It was the substantial expansion of staff at the St. Andrews Biological Station following the Second World War that permitted a substantial increase in offshore research in southern waters. There were still severe limitations in terms of research platforms and much of the early offshore work was conducted aboard commercial vessels either while they were engaged in normal fishing operations or under charter. The largest vessel in the research fleet was the 84.5 ft wooden-hulled Harengus, built in 1946 as a herring seiner but converted to a side trawler. This vessel could operate in offshore waters but its scientific accomodations were limited. (It operated as a research vessel until decommissioned in 1976.) The first vessel designed and built specifically as an otter trawler for fisheries research on Canada's Atlantic coast was the 177 ft steel side trawler A.T. Cameron. Delivery of this vessel in 1958 ushered in a new era for Canadian fisheries scientists. This vessel operated out of St. John's and, by arrangement between the two Atlantic coast Biological Stations, spent about one-third of its time in southern waters. The next addition to the Atlantic fisheries research vessel fleet, the 130 ft steel stern trawler E.E. Prince, was delivered in late 1966. This vessel was based in Halifax and was designed for work in more southern waters.

Throughout the 1960's and 1970's, it was still necessary to supplement the meager availability of dedicated fisheries research vessels by the frequent utilization of other vessels. Charter of commercial fishing vessels was common, and sometimes preferable to utilization of research vessels when the specialized knowledge of skipper and crew, and/or specialized design of the vessels, made them uniquely suitable for the purposes in mind. They were more frequently poor substitutes, however. The fisheries patrol vessel, Chebucto, which had a basic oceanographic capability, was occasionally used, as were the Canadian Navy Auxilliary Vessels Fort Francis and Sackville. The latter two vessels and the Kapuskasing were ex-Second World War navy vessels. The Kapuskasing was taken over after the war and operated by the Department of Mines and Technical Surveys for its Hydrographic Service and was occasionally available for fisheries related work. The Hudson and the Dawson, oceanographic ships operated by the Bedford Institute of Oceanography have also been occasionally used. These vessels had little in the way of facilities for biological sampling other than for towing of plankton nets, and this limited their usefulness for fisheries research. With Canadian extension of fisheries jurisdiction in 1977, additional resources, both in terms of manpower and vessels, were made available for fisheries research. As of 1980, this had little impact on the overall level of Canadian research efforts in NAFO Subarea 5, although acquisition of the Lady Hammond allowed more frequent expeditions to Georges Bank. This vessel has been employed as a full-time fisheries

research vessel since 1978 under a long-term charter arrangement. Initiation of the Canadian Observer Programme, which places observers aboard Canadian and foreign fishing vessels during normal commercial operations to observe these and to take biological samples of the catches, has also resulted in fairly frequent visits to Georges Bank since 1977.

It has proved most convenient to arrange this report on a species group basis (topic basis in the case of Oceanography) and to follow, more or less chronologically, research developments within each group. Sources have not been cited in the body of the report for various reasons, including ease of reading. A bibliography provides a listing of the most important source documents used in preparation of this account, and Appendix 1 provides a listing of the Canadian contributions to the scientific literature on fisheries and oceanography of Subarea 5. Appendices 2-4 list the Canadian at-sea presence in the area and Appendix 5 lists physical oceanographic measurements made. Most of these at-sea ventures are documented in Department of Fisheries and Oceans files in the "Cruise Report" series and these reports have been used extensively. Occasionally, when documented sources have failed, the authors' memories provide the source, although these have been relied upon as little as possible. Collectively, the authors' direct experiences do, however, span the period in question from 1926 until the present day, with substantial overlaps to provide corroboration. Thus, introduction of the occasional personal memory, substantiated by those of colleagues whenever possible, probably does not greatly affect the reliability of the report.

Groundfish

Canadian research on groundfish started in 1914 with growth studies on cod and hake and general life history studies of haddock. This early work was confined to coastal waters and the first research study by a Canadian which included groundfish on Georges Bank was conducted in the period 1926-29 and published in 1931. This comprehensive study of the migrations of haddock and the inter-relationship of haddock populations in North American waters was extended into Subarea 5 using unanalyzed USA material (tagging results and scale and length samples) provided in return for similar material on cod collected in more northern waters by Canada. The study found that adult haddock stocks on either side of the Northeast Channel were distinctly different, suggesting that the Channel formed a barrier to adult movements. A Canadian also produced a statistical review of the haddock fishery in all North American waters and this was published by the US Department of Commerce in 1930. This cooperation typifies USA-Canada fisheries research relations. From the first establishment of Canada's Atlantic Biological Station in 1899 there is evidence of exchange and cooperation with USA scientists.

Major changes in the Georges Bank haddock fishery in the 1920's, a time when this was entirely a USA fishery, caused the USA Government to start an intensive investigation of the haddock fishery in 1931. (This intensive investigation dominated the work of the Woods Hole Laboratory of the US Fish and Wildlife Service for the next 40 years or so, making Georges Bank haddock one of the best-studied fisheries resources in the Northwestern Atlantic.) The creation of the International Commission for Northwest Atlantic Fisheries (ICNAF) in 1950 provided a vehicle for fisheries regulation and at the first annual meeting in Washington in April 1951, the USA proposed a minimum mesh size regulation for haddock in Subarea 5. (USA federal authorities did not have authority to regulate domestic fisheries except to implement an international agreement.) The otter trawl mesh size in use was 2 7/8" and a substantial proportion of the catch was being discarded at sea. The ICNAF Commission agreed that a minimum mesh size should be established but, reflecting the uncertainty of the Standing Committee on Research and Statistics (STACRES), could not agree on the precise mesh size to be established. It was recommended, therefore, "that scientists representing the United States and Canada together consider this problem" and come forth with a resolution. Thus, although essentially all of the data on the Subarea 5 haddock fishery was USA data, this recommendation brought Canadian and USA scientists into a partnership for their analysis on a more formal basis than in the past. This was the beginning of what was to prove to be extensive regulatory action by ICNAF on the control of mesh size throughout the ICNAF Area.

This task was given a high priority by Canadian scientists and they participated fully in three meetings of Scientific Advisers to Panel 5 of ICNAF between the 1951 and 1952 Annual Meetings and at the Annual Meeting of 1952 itself. As a result of these meetings, a minimum mesh size of 4½" was recommended and adopted for haddock in Subarea 5, and it came into effect in June 1953. The need to prevent blocking of meshes was also recognized and the regulation prohibited devices which blocked the meshes. The scientific rationale for the 4½" regulation was that it would essentially eliminate discards, which would do no harm and might do some good. It was not generally accepted that there would be substantial benefits in terms of increased future yields through growth of released fish, let alone agreement on how large these benefits might be. The regulation was considered to be experimental in nature and a research programme was devised to evaluate it.

The Subarea 5 regulation was based on scanty data on mesh selection, much of it of European origin. There were also practical difficulties forseen in enforcement of the regulation on USA trawlers which fished in Subarea 4 as well as Subarea 5, providing a regulatory loop-hole. This resulted in USA pressure for extension of mesh regulation to haddock in Subarea 4. Since, in Canada, cod from Subarea 4 were of equal or greater importance than haddock, cod would have to be included in the regulation as well. In 1951-53, Canada placed observer teams on 13 trips of Canadian otter trawlers to determine their discard practices in relation to cod and haddock. It was found that, except when spawning concentrations were being fished, haddock discards ranged from 15-50% of the catch by number. The reason for the discards lay in a market preference for large haddock, the acceptable size being 42 cm or larger in 1953 (but haddock as small as 38 cm was landed from some of

the otter trawler trips sampled). The data on discard rates for cod were inconclusive. The results provided useful background to mesh size considerations for Subarea 4, the mesh size in use by Canadians being 2 7/8" - the same as the USA fleet had been using in Subarea 5 prior to regulation. Canada also began mesh selection experiments for cod and haddock in 1953, with three trips being made on chartered commercial vessels. The results, using 4½" to 5 1/4" mesh sizes, illustrated that selection with these larger meshes was consistent with expectations from earlier experiments with smaller mesh. Reduced selection resulting from use of "chafing gear" was also demonstrated. (Chafing gear is material fastened to the codend of a trawl net to prevent or reduce net damage.)

In order to be able to extend mesh regulation from Subarea 5 to Subarea 4 it was imperative to obtain selectivity results for cod, other species and smaller vessels. The fishery in some parts of Subarea 4 was more mixed than in Subarea 5, particularly that for cod and flatfish in the Gulf of St. Lawrence. Canadian efforts in 1954, in Subarea 4, concentrated on mesh selection for cod by small vessels using both the research vessel Pandalus II and a chartered commercial dragger. The results showed that selectivity on small and large vessels was similar and that a 4½" mesh did not allow the escape of commercial sized cod or American plaice. As a further contribution to this general problem area, the Newfoundland Biological Station had conducted research on discards in 1952 and 1953 and initiated mesh selection experiments on haddock in Subarea 3 in 1954.

There was a major Canadian effort prior to the 1955 Annual Meeting of ICNAF to compile and analyze all available material to support a regulatory initiative and this material was evaluated by the Scientific Advisers to Panels. The result was agreement at the 1955 meeting to regulate the mesh size used for both cod and haddock in all of Subareas 3, 4 and 5. The mesh size specified was 4½" for Subareas 4 and 5, but 4" for Subarea 3. These regulations took effect during 1957.

Canada conducted further research in 1955, in Subarea 4, on mesh differentials due to materials and on chafing gear effects on selectivity. Further work on selectivity for redfish, as well as for cod and haddock, of different materials and chafing gear arrangements was conducted in 1956 and new work was done on the effects of doubled-codends. A major review in 1957, of gear selection for the species and gears fished in the ICNAF Area, largely "wrapped up" the most active phase of gear selection research in the ICNAF Area. This review was a joint effort between Canadian and USA scientists. Occasional work was subsequently conducted by Canada on specific problems. Further chafing gear studies were conducted in 1958, and the selective properties of the new materials terylene and courlene were investigated on their introduction in 1959-60. The impact of the 1957 regulation on discards was monitored in the 1957-59 period. The results of this research, combined with that from other areas, resulted in amendments to mesh regulations, eg. the introduction of mesh size equivalents, based on material, which was agreed to in 1964. These were applicable to Subarea 5 as well as other parts of the Convention Area.

The USA-Canada cooperative efforts of 1951-52 which resulted in establishment of the Subarea 5 haddock mesh regulation also continued along other, complementary, lines, with substantial activity in the late 1950's. These emphasized practical and theoretical methods of scientifically evaluating the impact on stock dynamics, and yields, of mesh size changes, with Subarea 5 haddock being the study stock. The problem of comparing yields before and after regulation proved to be a thorny issue and joint studies delved into the reliability of data, and variances associated with estimates of year-class strength and mortality estimates. It was found that errors of estimation could completely mask changes predicted to result from regulation unless some of the major sources of error could be identified and accounted for. Canadian scientists developed and documented the "study fleet concept" requiring a designated part of the fleet to fish with large mesh prior to regulation and with small mesh subsequent to regulation. This was calculated to give estimates of comparable precision to available methods but with much shorter data series. The concept was never utilized, however. Another study, conducted jointly, examined first the reliability of ageing techniques used by the two countries (using scales versus otoliths) and the effects of ageing errors on estimates of mortality and year-class strength. Errors were found to be of sufficient magnitude to smooth out year-class strength differences with age and to make mortality estimates suspect. The extensive Georges Bank haddock data provided a basis for evaluating a new Canadian method of estimating fish mortality and gave new insights into the problems of interpreting fisheries data.

These quantitative population dynamics studies in the 1950s, which focused on Georges Bank haddock and the effect of mesh size regulation, were of substantial scientific import. They contributed to present day population dynamics theory and methodology, the evolution of which occurred in this period. This quickly found application. At its 1959 Annual Meeting ICNAF requested scientists to assess the long and short-term effects of various further increases in otter trawl mesh size on the catch and landings of fish in the Convention Area. A working group was formed which met several times in 1960 and 1961 and produced a final report which was published in 1962 (Beverton and Hodder [eds.], 1962). This group, which included substantial Canadian participation, brought together data on stock structure, growth rates, fishery statistics, mesh selection studies and population dynamics theory, to provide a definitive statement on the impact of mesh regulation on the major ICNAF groundfish fisheries. This report was unequivocal about the relative long-term effects on yield of changes in mesh size and set the framework of thinking within which mesh regulation has since been considered.

The developing modern theory of the effects of fishing on the dynamics of fish stocks had an impact on Canadian groundfish research programmes about 1945. Emphasis changed from general biological studies and "fisheries development" to documenting

fishing operations and their impact on resources. Programmes were initiated to sample the sizes and ages of fish in commercial catches and to set up a fisheries statistical system which recorded area of capture (rather than port of landing) and fishing effort. Emphasis was given to the definition of populations or "stocks" and to the study of their seasonal migrations, growth and mortality rates. The creation of ICNAF in 1950 gave new impetus to this work. Canadian scientists estimated area of capture of historical landings, and these estimates were presented to ICNAF in 1952. This report gave area of capture of redfish from 1936, and of haddock, cod, halibut, flounder and other groundfish from 1933. No groundfish landings were recorded from Subarea 5 up to, and including, 1951. The breakdown was based on estimates, and thus there is the possibility of some small amount of fishing in Subarea 5 being overlooked or ignored.

The focus of Canadian groundfish fisheries was historically "to the east" and so, naturally, this area became the focus of Canadian groundfish research. With the strong USA groundfish research presence on Georges Bank and the lack of a Canadian fishery, sharing arrangements were made to split the work on a practical basis reflecting relative priorities and available manpower. The St. Andrews Biological Station staff focussed their attention on the cod and haddock resources of the central and eastern Scotian Shelf and southern Gulf of St. Lawrence, which supported major Canadian fisheries. In 1955, the St. Andrews and Woods Hole laboratories embarked on a new venture in the cooperative study of haddock stocks in Subarea 4. This involved all Canadian data on the haddock stock in Div. 4X being shipped to the USA for processing and analysis and all USA data for the Div. 4W haddock stock being shipped to Canada. This reflected the predominance of fishing interests in these stocks at that time. In the early 1960's, the Canadian trawler fleet moved "to the west'ard" onto Browns and Georges banks and, with Canadian dominance in the Div. 4X haddock fishery, the former arrangement was terminated in the early 1970's.

There were locally important coastal fisheries for groundfish around southwestern Nova Scotia and the Bay of Fundy, mainly for haddock and cod, but to a smaller extent for pollock, which received some attention. The early work on haddock stocks and migrations in this area, in the late 1920's was followed by work on cod migrations and stock structure, mainly through tagging, in the 1930's. The early activities of ICNAF re-emphasized the importance of the definition of stocks, and a substantial inshore tagging operation was mounted off Lockeport in the summer of 1953 which resulted in the release of 1800 cod and 600 haddock. The results confirmed earlier work that, for both cod and haddock, the inshore southwest Nova Scotia-Browns Bank stocks were fairly well separated from those on Georges Bank in their adult life-history stages. A further substantial effort directed at haddock was mounted in 1957 as a USA-Canada collaborative effort under the umbrella of the International Passamaquoddy Fisheries Board of 1956-59. The USA tagged about 500 haddock from the Albatross III in Div. 4X, 5Y and 5Z. Canadians ventured offshore to Browns and LaHave banks in March and April in the 70 ft. J.J. Cowie to tag 1100 haddock. Returns from these offshore taggings were poor, but inshore tagging was more successful. Canada tagged 1200 haddock in the Bay of Fundy and the USA tagged in the Gulf of Maine as far east as Grand Manan Banks. The Canadian research indicated quite clearly that the haddock occurring on the New Brunswick side of the Bay of Fundy are a summer feeding phase of the Div. 5Y stock which spawns in the vicinity of Jeffreys Ledge. There was a suggestion that the fish on the Nova Scotia side of the Bay belonged primarily to the Browns Bank stock. This was subsequently confirmed by taggings in 1963 and 1966. Although Canadian efforts were all confined to Div. 4X with regard to initial tagging sites, the approach to groundfish stock separation in the Div. 4X-Subarea 5 area was, to a fair extent, a cooperative one between the USA and Canada, and the countries' efforts were complementary in addressing problems in the area as a whole.

In the late 1950's, pollock had become of increasing importance to Canadian fisheries, particularly in the southwestern Nova Scotia - Bay of Fundy region. A study of the biology of pollock at the mouth of the Bay of Fundy was initiated in 1960 and carried to completion in 1962. Of particular interest were the results of tagging in the Campobello and Grand Manan areas (500 fish at each location), close to the Div. 5Y-4X border. The migration pattern was remarkably similar to that observed for haddock with a predominant southern migration in autumn to the winter spawning area in the southern Gulf of Maine, particularly around the mouth of Massachusetts Bay, with a few fish going to the Scotian Shelf. No further research was conducted and when it became necessary to set catch limitations on pollock in the early 1970's, the relationships between Div. 4X and Subarea 5 pollock were recognized by managing them as a single unit. Subsequently, Div. 4VW were added to form a single pollock regulatory unit - Div. 4VWX and Subarea 5. The first stock assessments for this resource were conducted jointly by USA and Canadian scientists but, with extension of jurisdiction, more recent assessments have been done independently. Scientists of both countries still use the combined Scotian Shelf - Georges Bank - Gulf of Maine fisheries as the basis for assessment. Canada has recently been addressing the stock structure question again. Tagging experiments conducted in a wide variety of locations along the coast of Nova Scotia and around the Bay of Fundy have resulted in over 30,000 juvenile fish being released in 1978-81. A previously unknown relationship between Scotian Shelf pollock and those on the Northeast Peak of Georges Bank has been demonstrated and ichthyoplankton sampling has established the occurrence of pollock spawning stocks on the Scotian Shelf. The relationship between Bay of Fundy and Gulf of Maine fish observed in the early 1960's work has not yet been reconfirmed.

The early 1960's saw the development of small-mesh fisheries by eastern European fleets for non-traditional species in both Subareas 4 and 5. The largest fisheries were for silver hake, although the Atlantic argentine was a significant "by-catch" or incidental species. Early research included efforts to resolve silver hake ageing problems and, in 1964, otolith exchanges between the USA, USSR and Canada were arranged. (The problem was not

resolved, as ageing differences proved a major bone of contention between USSR and Canadian scientists involved in the assessment of the Scotian Shelf silver hake in the 1970's. ICNAF sponsored several ageing workshops in the mid-1970's.) These new fisheries stimulated Canadian scientific interest in the potential for domestic fisheries development. The commercial trawlers Louise P. and P.J. Lawrence were chartered in the summers of 1965 and 1966-67 respectively, for exploratory fishing. These explorations for silver hake and argentine were combined with explorations for herring, lobster and red crab, with four cruises being conducted in July-August 1965 between the southeast part of Georges Bank and Sable Island. Three surveys for these species were conducted in June-July 1966 between eastern Georges Bank and Banquereau. In July-August 1967 a further two surveys were conducted from Georges Bank to Banquereau for silver hake, argentine, and sand lance. These cruises were quite successful in obtaining information on these species although the results did not lend encouragement to the idea of developing Canadian fisheries. This and later Canadian work on the argentine, the main stocks of which appear to occur in the Northeast Channel area, suggested that it is a slow growing, late maturing, species with a limited yield potential in relation to its standing stock. Subsequent work on silver hake concentrated in Subarea 4 with the exception of some comparative studies on the feeding of silver hake in Subarea 4 versus 5.

In the mid 1960's, the USA proposed that ICNAF sponsor a major new environmental survey to be carried out in the Georges Bank area to study the effects of the environment on the recruitment of haddock. Plans were formulated, with some Canadian participation, in the 1965-67 period and the initial stages of the work were to focus on experiments on the design, conduct and analysis of a zooplankton sampling programme. Canada had just started a programme with somewhat similar objectives for cod in the southern Gulf of St. Lawrence and was not in a position to commit herself to another routine survey programme. Canadian scientists were interested in the gear and experimental design tests, however, as these had relevance to their own work. The Canadian charter vessel Theta joined vessels from USA and USSR on Nantucket Shoals in September 1968 to investigate the effect on estimates of abundance, of sizes of plankton samplers, mesh sizes, speed and length of tow, and tow profile. The USA and USSR persisted with the programme in 1969 but it did not attract the international support it required for full implementation and no further field work was done. The USA scientists diverted their efforts into herring larval and, subsequently, MARMAP sampling programmes involving broad-scale surveys of Georges Bank and adjacent areas which were conducted continuously from the early 1970's. Canada terminated the southern Gulf of St. Lawrence ichthyoplankton surveys in 1975 and directed attention in 1976-78 to development of a broad-scale ichthyoplankton survey on the Scotian Shelf and adjacent areas to the south. A standardized station grid, which was adopted in 1978, included the eastern part of the Gulf of Maine and a large proportion of Georges Bank. However, the logistics of occupying this 245 station grid proved impractical and, in 1979, it was reduced to 150 stations of which about 5 were located on the northeast part of Georges Bank. About 15 Georges Bank stations in the original (1978) station grid were occupied once in 1978, and the revised grid of about 5-7 stations on Georges was occupied twice in 1979 and thrice in 1980.

The Canadian offshore trawler fleet activities expanded to include Georges Bank about 1962, directing their fishing mainly for haddock, although cod and pollock were important ancillary species. Haddock catches increased annually to a maximum of 19,000 mt in 1966. The abundance of Georges Bank haddock declined rapidly in the late 1960's and Canadian catches could not be sustained. Canadian research practice of comprehensive fishery monitoring resulted in general data collection from this developing Subarea 5 fishery starting in 1963 with collection of catch and fishing effort data and biological sampling of commercial landings. In 1964, scientific observers accompanied three commercial trips to the Georges - Browns banks region to assess the haddock discard situation. Another observer trip was made in 1966 and these operations indicated that discards were not a significant problem in the Canadian fishery on Georges. The data collected on the Canadian fishery were made available to USA scientists. Canadians produced general descriptions of the distribution of Canadian trawler catches of cod and haddock on Georges Bank (and areas to the north) based on trawler operations in 1965 and 1967.

In the 1960's, ICNAF wrestled with the problem of rapidly expanding fishing effort and means for its control. Introduction of catch controls (TAC's) were receiving favourable attention, and in the scientific considerations of how to determine appropriate levels of catch at which to regulate, Georges Bank haddock was identified as one of only two stocks for which data were considered adequate. This was perhaps fortuitous as the rapid collapse of the Georges Bank haddock fishery in the late 1960's was clearly documentable and it was this collapse which precipitated ICNAF into TAC regulation of fisheries. The inter-relationships between the haddock fisheries on Browns and Georges Banks, with both the USA and Canada major participants in both, favoured a regulatory approach which covered both fisheries, thus reducing problems from diversion of effort. The regulations agreed to in 1969 included TAC's for both Div. 4X and Subarea 5 and also included season and area closures to protect spawning haddock in both areas. The coordinated USA-Canada approach to proposing the regulations included thorough consultations and agreement between the scientists of the two countries on the measures to be proposed. Thus, there were clear parallels between the approach taken to this major new regulatory venture by ICNAF and that taken to the introduction of mesh regulation almost 20 years before.

In subsequent years, USA scientists spearheaded regulatory initiatives in Subarea 5 and Canadian scientists spearheaded those in more northern areas. The Canadian contribution to groundfish assessment in Subarea 5 was largely in the nature of critical comment and review, a role reciprocated by USA scientists for the groundfish assessments in more

northern areas. Canadian scientists played a rather more direct role in relation to the USA proposal for the introduction of fishing effort regulation in Subarea 5+6 in 1973-74. Canada participated on a "Working Group of Experts" which, in a series of three meetings during this period, evaluated the basis for, and the practicality of, effort regulation. This included analysis of Canadian fisheries, particularly groundfish fisheries, in Subarea 5 and the factors affecting effort control. The proposal was not implemented.

Expeditions to Subarea 5 by Canadian research vessels for study of groundfish have been rare in relation to those for other species of importance to Canada's fisheries such as herring, scallops and swordfish. The exploratory cruises of 1965-67, the venture of the Theta in 1968, and the scanty coverage of northern Georges Bank in the ichthyoplankton sampling of recent years, have been mentioned above. To these can be added a visit by the E.E. Prince in July 1968 while engaged on a survey of the general distribution, abundance and biological parameters of groundfish in Div. 4X and 5Z. The E.E. Prince returned 10 years later in April 1978 to sample haddock for infestation by the protozoan parasite Eimeria gadi, extending a study conducted on Scotian Shelf haddock stocks. The A.T. Cameron sampled northern Georges in the winter of 1977 as part of an investigation of haddock distribution in relation to the closed areas on Browns and Georges banks. Coverage was missed in 1978 but repeated in March 1979 by the A.T. Cameron and in March 1980 by the Lady Hammond. With the substantial USA survey effort in Subarea 5, particularly after acquisition of a new research vessel Albatross IV in 1963, and establishment of standardized routine groundfish surveys in spring (from 1968) and fall (from 1963), scarce Canadian research vessel effort was judged to be more effectively expended elsewhere.

In summary, groundfish research cooperation between USA and Canadian scientists has focused on Georges Bank and adjacent areas which have proved to be the crucible for many of the developing groundfish management problems, and the testing grounds for their solution. There was substantial Canadian analytical activity on USA data in the 1950's, and much complementary research in adjacent Subarea 4, particularly on stock separation and mesh selection questions.

Pelagic Fish

Small Pelagic Fish

Mackerel. The North American Council on Fishery Investigations (NACFI) provided a forum for cooperation between USA and Canadian scientists in the period between 1921 and the start of World War II. It sponsored statistical reviews of various species fisheries intended as background for fisheries management research and as an aid to assessing the need for management measures. Such a review for the mackerel fishery, which extended along both USA and Canadian coasts and was prosecuted by fishermen of both countries, was produced by the joint effort of a Canadian and a USA scientist in 1934. The mackerel fishery was relatively unimportant among Canadian fisheries and in general it received scant attention. A series of cruises in 1961-62 by the A.T. Cameron and Harengus, exploratory fishing for pelagic fish in general in the Georges Bank region, listed mackerel as one of their target species, but these met with no success in catching mackerel and the species was dropped from the list of objectives for future cruises.

In the mid to late 1960's general research was conducted on mackerel biology and its fishery. This work concentrated on the summer spawning and feeding area in the Gulf of St. Lawrence but some stock separation studies, with regard to the hypothesized "northern" and "southern" contingents, were conducted in 1965-66. This involved a cooperative effort with USA scientists who provided X-ray plates of mackerel sampled at Provincetown, Mass., and the vertebral counts of these fish were compared with those of fish taken off Halifax, N.S. This cooperation also included electrophoretic comparisons of heart and muscle tissue of 500 fish taken from both the Gulf of St. Lawrence and Cape Cod Bay. The work did not demonstrate differences.

The rapid expansion of the mackerel fishery in Subareas 5+6 in the early 1970's was partly responsible for increased Canadian research activities, particularly sampling of catches and tagging. Stock assessment of mackerel became a highly controversial matter and the ICNAF Assessments Subcommittee set up an ad hoc Mackerel Working Group in May 1973 to deal with it. This working group assessed mackerel in Subareas 5+6 but the first tag returns from Newfoundland taggings were already available to indicate migration from Newfoundland to the New York Bight, and hence the likelihood of a mixing problem between northern and southern stock contingents. Further Canadian tagging results in 1974 from Subarea 4 taggings confirmed substantial movement of the northern stock to, and exploitation of it in the winter fishery in, Subareas 5+6, and a TAC for Subarea 3+4 mackerel was recommended by STACRES of ICNAF. In 1975, the ICNAF Assessments Subcommittee did a combined assessment of mackerel in Subareas 3-6, and Canadian scientists presented one of three assessments used as the basis of ICNAF considerations. More extensive data on the migrations of mackerel tagged off Newfoundland, and of mackerel tagged in the Gulf of St. Lawrence and off St. Margarets Bay, Nova Scotia, were published in 1975 and 1976 respectively. Canada mounted a survey of overwintering distribution of mackerel in Subareas 4-5 from mid-November to mid-December 1976 using the research charter vessel Cape Argos. Although some proportion of the age 0 and age 1 population could well be overwintering on the Scotian Shelf, no conclusive evidence was obtained which challenged the hypothesis that the bulk of the northern contingent overwinters in Subareas 5+6 and contributed significantly to the international fishery there. With extensions of jurisdiction, third party fishing for mackerel was terminated. Canadian and USA scientists assessed the stocks independently, although both continued to treat Subareas 3-6 mackerel as a unit.

In summary, Canadian interest in mackerel research developed as the international fishery developed in the early 1970's. It concentrated on determining the extent to which mackerel spawning in

Canadian waters contributed to the international winter fishery in USA waters in the New York Bight, and on developing an independent stock assessment capability.

Herring. Among the pelagic species, herring supports by far the most important Canadian commercial fishery. The Gulf of Maine, Georges Bank, Bay of Fundy area contains a complex of important herring stocks which have long supported large fisheries by both the USA and Canada and, for a period of about 15 years, also by third parties. The approach to herring research in this area has been one of extensive cooperation between the USA and Canada and, because of the unknown, but obviously complex, inter-relationships among herring throughout the area, there has been a strong tendency to consider the whole area in research plans.

Canadian studies of herring in the Bay of Fundy area date back to about 1900 when a portable laboratory was built and located at St. Andrews, N.B., as a base for fisheries research. Work on Bay of Fundy herring was conducted during the Canadian Fisheries Expedition of 1914-15. In the late 1920's, Canadian studies of the potential effects of dams proposed for construction in the Passamaquoddy area were giving rise to predictions of considerable damage to herring fisheries of the area and, among other areas, down the coast of Maine. It was as a result of the tidal power project proposals for this area that the Governments of the USA and Canada, at the urging of NACFI, set up the International Passamaquoddy Fisheries Commission in 1931 to investigate the ecological impacts. Canadian efforts in this Commission's joint programme took Canadian researchers into the Gulf of Maine, and as far as Georges Bank for the first time. Canadian research on larval and juvenile herring and on phytoplankton provided the Canadian input to the Commission. The results of the Commission's work were inconclusive for its principal purpose - to predict the effects of power dams on the sardine fishery of Charlotte County and neighbouring Maine. Nonetheless, they did provide useful background for an understanding of the biological productivity of the area, and for future work.

There was no herring research conducted by Canada in the late 1930's, but in the early 1940's a substantial interest arose in developing new fisheries on what was seen as a great unused resource. This translated into a programme of extensive exploratory fishing and by 1953 these exploratory activities reached Georges Bank. The commercial trawler, using a Dutch herring trawl, chartered for this research did only 15 tows on Georges Bank and caught no herring - hardly an auspicious start. In the summer of 1955, however, Canadian biologists were back on Georges Bank. A drift net fishing operation in late July was of little success but fishing with a Dutch herring trawl in late August-early September was successful in catching some quite large quantities of herring. These were large adult ripe and running fish considered to be in the process of spawning. Canadian explorations continued in July to early September of 1956 in the Bay of Fundy - Gulf of Maine region. Georges Bank was re-visited and substantial quantities of mature herring were again taken in the same locations as in 1955. This gave evidence of the persistent occurrence of a large herring spawning population on northern Georges Bank in August and early September. This persistence was established in brief cruises to the area in 1957 and 1958. (The expedition in 1957 was made chiefly to obtain samples for population studies and the material was used in a comparative study of vertebral counts among herring from different areas. The results were inconclusive but mark the beginning of extensive research on stock separation based on biological characteristics.) Prior to 1955, records of small quantities of herring being caught on Georges Bank, mainly by USA fishermen, were not uncommon, and "brit" herring had been taken on the northern and eastern parts of Georges Bank by USA scientists in the spring of 1920. However, Bigelow and Schroeder (1953) concluded that there was no definite record of herring spawning on Georges Bank, nor records of larvae. Thus, it appears that it was the Canadian work which established the existence of a large Georges Bank spawning stock.

The question of a tidal power project in the Passamaquoddy Bay area arose again in the mid-1950's and the governments of Canada and the USA referred the matter to the International Joint Commission to examine, among other things, the effects upon the fisheries of the area. The Commission established two boards, one of which was the International Passamaquoddy Fisheries Board (IPFB) charged with the task of forecasting fishery effects. The Board worked through a Research Committee of government scientists from the Fisheries Research Board of Canada and the Bureau of Commercial Fisheries of the United States. The research programme placed major emphasis on herring as this species was by far the most important in the area likely to be affected. Studies on herring sponsored by the Board were wide ranging, including analysis of the fishery, herring growth, their physiological and behavioural reactions, their food, stock structure and distribution. Of particular note in the present context was the extensive Canadian involvement in joint studies of the occurrence and distribution of larval herring throughout the Gulf of Maine-Georges Bank region. From 1956 to 1959, Canada ran a series of autumn and winter surveys, mainly with the Harengus but also with the A.T. Cameron, Sackville and Fort Francis, in coodination with a variety of USA vessels. In combination, these efforts not only confirmed spawning on the northern edge of Georges Bank but established that this, along with the southwestern Nova Scotia area, supported the two largest spawning populations in the area. Small spawnings were located in various areas along the coast of Maine. From the drift of larvae it was suggested that the Nova Scotia spawners are major contributors to commercial stocks in inshore areas of southern New Brunswick and eastern Maine. The IPFB report also speculates that Georges Bank spawners were also supplying some herring to the area.

The IPFB reported to the International Joint Commission in 1959, the Passamaquoddy fisheries investigations officially running for the period 1956-59. Canada continued to pursue the question of the origin of Charlotte County sardines. In 1960, larval surveys were conducted off southwestern Nova

Scotia and down to Georges Bank on the Sackville. The gap in larval distributions between Georges Bank and southwestern Nova Scotia was considered evidence against a Georges Bank contribution to New Brunswick sardine fisheries. A study of otolith characteristics among herring from Georges Bank and other areas was unsuccessful in casting light on the problem.

In the period 1961 to 1966, Canadian herring research in Subarea 5 was largely routine monitoring. The multi-purpose pelagic fish cruises conducted mainly by the A.T. Cameron included sampling the adult stock on Georges Bank, and plankton sampling for larvae, as standard objectives. The USSR initiated a large-scale commercial herring fishery on Georges Bank in 1961. This expanded throughout the 1960's with various other European nations entering the fishery in the mid-1960's. Canadian adult sampling data collected in the late 1950's and during the developmental phase of the fishery in the early 1960's was of importance in interpreting events in this new situation. Later data were too scant, relative to other data sources, particularly from the commercial fishery, to be of much importance. Sampling Georges Bank adult herring remained a routine Canadian cruise objective until 1970, but received low priority after the mid-1960's.

In 1965 and 1966, Canada conducted more exploratory fishing for herring (along with other species) on the offshore banks from Sable Island to Georges Bank in an attempt to encourage Canadian exploitation of offshore herring stocks. Best catches were made in the Corsair Canyon region of Georges Bank but overall results were not particularly encouraging. Possibly coincidentally, the Canadian purse seine fleet entered the Subarea 5 herring fisheries the following year. Beginning in 1967, a substantial fishery for adult herring was developed in the western portion of the Gulf of Maine concentrating on Jeffreys Ledge, Stellwagen Bank and adjacent areas. The Canadian purse seine fleet from the Bay of Fundy, which pioneered this development, took 7,000 mt in 1967 and a peak catch of 22,000 mt in 1968. Significant catches were taken until 1976. This same fleet also fished Georges Bank in the 1967-71 period but took significant catches of 13-14,000 mt in only two years, 1968 and 1971. In support of Canadian fishing operations in Div. 5Y, Canada conducted a research cruise on the E.E. Prince in November 1968 to survey the abundance of herring in the area from Campobello to Cape Cod Bay using echo sounder, sonar and midwater trawl. The distribution and abundance of herring were described from sounder and sonar records, but midwater trawling was unsuccessful.

USSR scientists carried out quantitative surveys on the extent and intensity of herring spawning on Georges Bank from 1964, using bottom grabs and dredges to sample deposited spawn. These surveys showed a progressive contraction in the area of spawning grounds and in estimates of total number of eggs laid, from which a corresponding reduction in adult stock size was inferred. There were various possible sources of bias in these estimates and the desirability of calibrating the surveys by direct observation was recognized. In September-October 1970 a co-operative field programme was mounted with the USSR contributing the research vessel Alferas, Canada contributing the submersible Pisces I and the USA contributing the Albatross IV. The Alferas was to locate the main spawning grounds and carry out the grab and dredge survey as in previous years, while the Pisces, using the Albatross IV as a mother ship, observed the located spawning beds in detail. Three spawning beds were detected by the Alferas, and the USSR scientists concluded these were the main ones. A bed marked by Alferas with a radar buoy was subsequently successfully located by the Pisces. This utilization of the Pisces was very much a developmental operation, and new survey and sampling techniques had to be developed. Observations were made on sediment preferences of spawning herring, the ontogeny of a spawning bed, the associated fauna, predation of herring spawn, herring larval behaviour, and on sedimentology of the area. It was not possible, however, to mount a sufficiently extensive operation to actually calibrate the USSR surveys.

Acquisition of the new research vessel E.E. Prince in late 1966 allowed planning of a new research initiative on oceanography and the distribution of ichthyoplankton, particularly herring larvae, in the Gulf of Maine Area. A three year series of four seasonal surveys was begun in February 1967, with an area of coverage which included the eastern half of the Gulf of Maine and eastern Georges Bank. This seasonal coverage was obtained in each of the three years 1967 to 1969, and two additional surveys were conducted in 1970, in a total of 16 separate vessel cruise operations. These surveys, while providing various results of interest, proved to have been conducted on too broad temporal and spatial scales to provide much greater insight into herring stock relationships than did those of the late 1950's.

The need for regulatory control of the increasingly intense international herring fisheries was beginning to be widely recognized in the late 1960's, and ICNAF became active both in herring stock assessment and in coordination of research. As one of its first efforts, ICNAF identified at its 1970 meeting that studies of the dispersal of larval and O-group herring from the main centres of spawning, especially on Georges Bank and in the Bay of Fundy, were research priorities. This required much more intensive surveys (spatially and seasonally) than had previously been conducted. Arrangements were made for four cruises on Georges Bank in the period September to November 1971 by vessels from the USA, France, USSR and possibly FRG. Provision of similar and complementary coverage of the southwestern Nova Scotia-Bay of Fundy area was left to Canada. Operations in 1971 were successful with 5 cruises on Georges Bank being conducted (the USA did two), 4 cruises were run by the USA in Div. 5Y and Canada ran one cruise in the Bay of Fundy in October. ICNAF named this the "International Herring Larval Survey Program" and planned to continue and intensify it in 1972. This set the pattern through the mid-1970's. Canada's contribution to the overall programme was the surveys in Div. 4X and the northern corner of Div. 5Y. Canada adopted a standard station grid for her November 1972 survey, and each year since this grid has been occupied (to the extent permitted by

weather) at least twice a year in spring and fall (maximum 4 times in 1974).

In the mid-1970's the International Herring Larval Survey Program became attached to a more general programme to determine the factors involved in production of good and poor year-classes. This required that the Georges Bank surveys be continued for several more years and that new projects on oceanographic processes and dynamics of larval aggregations (or "patch studies") be built around them. Although Canada had not been participating in the routine multinational surveys on Georges Bank, it was decided to participate in the special studies of larval herring dynamics. Both the E.E. Prince and the oceanographic ship Dawson participated in pilot projects on Georges Bank in 1977 in preparation for a planned major international multi-disciplinary, multi-ship larval herring patch experiment in October-November 1978 in the Georges Bank-Nantucket Shoals area. In 1978, three Canadian vessels participated. One was the oceanographic research ship Dawson. The other two were the fisheries research vessel Lady Hammond which did micro-scale larval distribution studies, and the chartered commercial vessel Canso Condor which did broader-scale studies on larval distributions and on potential predators. Five other vessels were involved from the USA (2 vessels), FRG, Poland and USSR. The field programme on Georges Bank was terminated in 1979 and analysis of the 10 year data series has been ongoing under the coordination of the NAFO Scientific Council. A great deal of new knowledge on herring larval biology and ecology has resulted although elucidation of the factors controlling year-class strengths remains elusive.

Stock separation was always a primary issue in herring research, and an intractable one. ICNAF had discussed initiation of cooperative herring tagging experiments in the Georges Bank-Gulf of Maine-Bay of Fundy area from 1971, but procrastinated in the face of anticipated difficulties. Canada proceeded unilaterally, starting by tagging 11,000 juvenile herring in November and December 1973 in the area around Grand Manan Island. More taggings were done in the Bay of Fundy-southwestern Nova Scotia areas in 1974 and 1975. In 1976, ICNAF addressed the question of undertaking a major international tagging programme again. On this occasion the proposal obtained support, based on the facts that Canadians had demonstrated herring tagging to be technically feasible and also that the tagging results were demonstrating inter-relationships between herring from southwestern Nova Scotia and the Gulf of Maine. A proposal was developed for a three year programme, and detailed plans made for 1976 and 1977, which called for application of close to 500,000 tags to herring from Div. 4R south to Statistical Area 6, but mainly in the Div. 4X-Subarea 5 area, by Canada, USA and USSR. The original plan for 1976 and 1977 was followed under Canadian coordination with a large measure of success. Canadian and USA scientists participated in offshore tagging on Georges Bank with USSR scientists aboard USSR vessels. USA scientists tagged on Jeffreys Ledge and inshore Gulf of Maine, while Canadian scientists tagged in the Bay of Fundy and to the north. With extensions of fisheries jurisdictions, cooperative arrangements broke down. More recently, cooperative analysis of the results was sponsored by the NAFO Scientific Council and the data yielded significant new insights into stock interrelationships in the area (NAFO Scientific Council Reports 1983).

In summary, research interest in the herring of Georges Bank cannot be readily separated from an interest in herring resources of the whole Georges Bank-Gulf of Maine-southwestern Nova Scotia region. Canada has demonstrated an interest in these resources from the turn of the century. The first Canadian presence on Georges Bank sensu stricto, for the purpose of herring research, appears to have been in the early 1930's, but there is an almost continuous annual record of presence there from 1955. Canadian work demonstrated the presence of a large herring resource on the Bank, a discovery which proved of great benefit to the eastern European fishing fleets in particular and of little benefit to Canada. Canada has participated in one way or another in almost all of the major research initiatives undertaken on herring in the area and in some cases, such as the tagging experiments, played the leading role. The efforts of Canadian scientists in the extensive work in ICNAF in the late 1960's and in the 1970's to establish a regulatory framework for effective control of herring exploitation throughout the area is much harder to document but had a substantial influence on the course of events. It is relevant in this regard that the chairmen of both the ICNAF and NAFO working groups on tagging and of the Herring Working Group of the ICNAF Assessments Subcommittee (1971-74) were Canadians.

Large Pelagic Fish

Canadian research on large pelagic fishes extended over all species which occur in the northwest Atlantic but swordfish received the most direct attention due to its commercial importance. The Canadian swordfish fishery began in 1903, and consistently took a greater share of the resource than the USA fishery from 1939 until the fishery was severely restricted in 1971 following the realization that the species contained high levels of mercury. The original Canadian fishery was conducted using harpoons and was seasonal in nature, starting in late June on Georges Bank and the Scotian Shelf and spreading north and east to the western Grand Banks by mid-September. Introduction of longlining in 1962 resulted in rapid conversion of almost the entire fleet to this gear and total catch, season and area fished all increased, with larger vessels fishing throughout the winter and spring as far south as Cape Hatteras.

Swordfish research was initiated in the early 1950's with investigations into its food habits. This began modestly with examination of 17 stomachs brought ashore from commercial harpoon vessels in the 1952 and 1953 seasons. The work on food and feeding habits was extended in 1958 with observations made at sea aboard a commercial fishing vessel, and a new investigation was begun to determine factors affecting swordfish distribution so that seasonal variations in their occurrence could be explained. This research was further expanded in 1959 and diversified to include observations on abundance and distribution and

length, weight, sex and parasites of fish caught. Four trips on commercial vessels were made that year with one of these working in the Nantucket-Georges Bank area. This increase in research was stimulated by the increase in landings and it was recognized that knowledge of migrations and stock relationships would be required for orderly fisheries development. Work in 1960 included first attempts at tagging from the research vessel Harengus on the Scotian Shelf but it turned out that further development of application techniques was required. The Harengus had some success catching swordfish with floating longline gear, these trials reflecting a growing interest in the commercial use of this gear.

This 1960 tagging expedition on the Harengus ushered in a decade of effort to tag large pelagic fish, and swordfish in particular. There was close cooperation between Canadian and USA scientists in these efforts. Canadians put a great deal of work into what proved to be a most difficult and frustrating task, due mainly to the technical problems of handling very large fish without damaging them. During the decade some 2,440 fish belonging to about 20 species were tagged. Swordfish proved the most difficult to tag and only 124 were released. Tag application was more successful for tunas and sharks although the returns from all these taggings were disappointingly low. However, the results, when combined with fisheries data and tagging results from elsewhere, provided significant clues to the movements of swordfish, bluefin tuna and, to some extent, blue sharks.

With the increased availability of research vessels, a more extensive and more diversified programme of research into large pelagic fishes was initiated. In 1961, three cruises were run with the objective of exploratory fishing for pelagic fish in general. The research vessels Harengus and A.T. Cameron (2 cruises) fished a variety of trawls, gillnets and line gear over an area which included much of Div. 4X and Subarea 5 and out to the Gulf Stream. Japanese longlines were most successful in catching large pelagics and catches of mackerel sharks were sufficient to suggest the possibility of commercial fishery development. This programme was repeated in 1962 with four cruises, two each by Harengus and A.T. Cameron, covering Div. 4X and the northern part of Georges Bank with similar results as in 1961.

The rapid switch in 1962-63 of the fleet to longlining for swordfish and the resulting major increase in landings (by about 3½ times in one year) refocused research on the swordfish fishery and presented new opportunities for biological research. Research in 1963 and 1964 concentrated on collection and analysis of fishery and biological data, including two trips by observers on a commercial longliner which fished Georges Bank in 1963. Further trips were made in 1964 one of which went to Georges Bank and one went south to Statistical Area 6. Work at sea included experiments to test effects on catch rates of bait type and hook size and of the water temperature and depth fished. In 1965, further observer trips were made on commercial vessels including one to Georges Bank and two to Statistical Area 6, and until 1969 one trip was made each year either to Div. 5Z or Statistical Area 6. By 1965, the fishery monitoring and biological analyses indicated that the increased landings resulting from conversion to longline were having a considerable effect on the stocks, in contrast to the days of harpooning when changes in the fishery related largely to environmental factors.

During the 1963-65 period, a Canadian fishery was developed for small- and medium-size bluefin tuna in the New York Bight to Georges Bank area. The vessels involved were two of the larger herring purse seine vessels from the Bay of Fundy fleet which had been specifically designed to be able to participate in this tuna fishery. Although the duration of this venture was brief, it was capitalized upon to tag bluefin tuna and collect general biological data on this species and on skipjack tuna, which were taken mixed with the bluefin tuna.

Research vessel-based research was not neglected. The A.T. Cameron was used to continue the general pelagic fish surveys on Georges Bank with cruises in 1964, 1965 and 1966. These were augmented by two cruises of the charter vessel Alder Point to the Georges Bank area in 1964 and extended to Statistical Area 6 using the E.E. Prince in 1967. A major new initiative was begun in 1965 to study the winter distribution of large pelagic species, and their reproductive ecology including the distribution of planktonic stages, in southern waters. The first expedition was mounted aboard the research vessel Hudson for the month of February 1965 in the area from Cape Hatteras to the Caribbean. Post-larval stages of swordfish were caught in three general regions - off Cape Hatteras, in the Florida Straits and in the northeast part of the Caribbean Sea. These results indicated that there are two or more spawning areas for swordfish in the western Atlantic. Further expeditions were mounted in the winters of 1966 aboard the A.T. Cameron, 1968 using the Hudson, 1969 and 1970 using the Sackville and in 1972 on the Dawson, all to waters south of 35°N. A cruise complementary to this series was run in April-May 1969 on the Sackville in more northern waters in Subarea 5-6 and south.

A cruise to Georges Bank on the Harengus in 1968 foreshadowed a problem which was to radically change the nature of the swordfish fishery - one of its purposes was to sample large pelagic fish for mercury content. Restrictions were placed on sales of swordfish due to regulation of mercury levels in food for human consumption by both the USA and Canada in 1971. Most swordfish exceeded the acceptable maximum level of 0.5 ppm total mercury and this resulted in almost complete cessation of the Canadian fishery. Field work in 1971 emphasized collection of samples for the study of mercury content. The Harengus collected on Georges Bank for a week in July and in October the charter vessel Dorothy & Gail sampled from Georges Bank south to Cape Hatteras. More collections were made in 1972 on the charter vessel Francis Geraldine, with a cruise in May working from off Cape Charles out to 55°W in the Gulf Stream and a second cruise in June working in the Gulf Steam and adjacent waters west of 68°W. An ancillary objective was to search for commercial quantities of tuna. Further field collections for mercury determination were undertaken in 1975 by the charter vessels Dorothy &

Gail and Scotian Maid and these vessels worked in both Div. 4X and 5Z. This work reflects continuing efforts to devise ways to reestablish a viable Canadian swordfish fishery. With relaxation of the Canadian mercury content regulations in 1979, the swordfish fishery was reactivated and field research on swordfish was again conducted. In 1980 the commercial swordfish longliner Jane R. was chartered from August to October to conduct a swordfish survey and general biological studies from Cape Hatteras north over Georges Bank and across the Scotian Shelf.

Abandonment of the swordfish fishery resulted in a revision of research priorities and more attention was given to bluefin tuna, the large pelagic species of next importance to Canadian fisheries. Tuna tagging work in particular had been going on for some time, and when the large tuna purse seiners which began operating out of St. Andrews in the late 1960's reinitiated Canadian participation in the bluefin fishery off New Jersey, the opportunity was taken to mount further tagging operations. In 1971 bluefin tagging was conducted aboard commercial vessels while in 1972 and 1973 the Harengus and E.E. Prince respectively operated cooperatively with the Canadian fleet off New Jersey. Subsequent work concentrated on studying the fisheries for large bluefin which occur in Canadian coastal waters. Although this de-emphasized work directly related to the Georges Bank region, it was relevant to the management of bluefin tuna in general in the northwest Atlantic and Canadian scientists played an important role in the analysis of bluefin tuna stock status on which managerial control of fishing was based.

In summary, Canada has demonstrated an active interest in research on large pelagic fishes, particularly swordfish and bluefin tuna, for about 30 years. This reflects the substantial Canadian fishery interest in these species and in the case of swordfish, the predominant interest for many years. These are oceanic species, the same stocks of fish ranging throughout the northwest Atlantic. Thus, work done anywhere within their range is relevant to management of the resource as a whole. Canadian research on large pelagics has ranged from the Caribbean to the Grand Banks, although the Georges Bank area has been a focus for much of the Canadian effort.

Invertebrates

Sea Scallops

Canadian scallop fishing on Georges Bank began on a small-scale, seasonal, basis in 1945. Increasing Canadian fishing effort directed towards scallops in the area stimulated Canadian scientific interest in this resource, and discussion of a cooperative research programme between Canada and the USA was carried out under the auspices of ICNAF's Standing Committee on Research and Statistics at its 1956 and 1957 meetings. The first Canadian efforts were directed toward improving catch and fishing effort data derived from commercial vessel log books and, by observing at-sea operations, determining the factors to be taken into account when interpreting catch rates as measures of abundance. Comparison of gear retention versus cull size on two trips to Georges Bank aboard commercial draggers in 1958 indicated that dredge ring size could probably be increased to reduce the numbers of undersized scallops caught and discarded. Initial observations on survival of discards indicated survival to be low, however, and this cast doubt on whether scallops passing through the dredge would survive in any case.

Although Canada had conducted research on scallops in the 1930s and 1940's, including occasional work on Georges scallops, this was given increased emphasis with employment of a biologist to work full-time on scallop investigations in 1959. In that year four trips were made on commercial draggers to Georges Bank to continue the work initiated in 1958. This early work on scallop population dynamics established two of the main thrusts of Canadian research on scallops - fishery monitoring and analysis and the related question of gear efficiency and effectiveness.

In 1959 an experiment was run to test the effect of using 4" rather than 3" rings in the dredge. The results indicated a slight increase in efficiency in catching market-sized scallops but the major advantage was a reduction in the amount of trash retained. This work was continued in 1960, with ancillary aspects of the problem relating to estimates of natural mortality and discard mortality being examined experimentally. The results were brought to the attention of the ICNAF Commissioners in 1961, who asked their scientific advisers to provide a basis for considering an appropriate regulation of ring size. In August-September 1961, Canada chartered the commercial scallop dragger Cape Eagle to obtain more data on ring size effects, and also to assess spatial variation in scallop density. All data from Canadian and USA sources were examined at the 1962 ICNAF meeting but they were considered an insufficient basis for a regulation which would increase ring size used. Scientific opinion was still that an increase in size of scallops caught would have benefits in increasing fishery yields, but lack of success in obtaining regulation of ring size resulted in this approach being dropped. In 1962, efforts were directed toward examining the overall performance of the 8 foot offshore-style drag by underwater observation. This work was conducted by the Harengus in the southern Gulf of St. Lawrence where scallop beds occurred in sufficiently shallow water for scuba divers to operate. However, the results were of general applicability. Preliminary results indicated that this drag is very efficient at catching market-sized scallops at the low densities which prevailed at the experimental site. This was followed in 1963 by comparative gear efficiency trials between inshore and offshore type scallop drags and modified otter trawls both in the Gulf of St. Lawrence by the Harengus and on Georges Bank by the A.T. Cameron. The results showed the offshore drag currently employed in the Georges Bank fishery to be the most efficient, and a hiatus in gear research followed. Some relevant work was done in 1967, again by scuba divers, which showed that scallops under 100 mm shell height exhibited avoidance reactions to approaching objects and direct observation illustrated that swimming activity, rather than selection, was responsible for the low efficiency of

'e offshore drag for scallops under 100 mm. The field work was conducted in the southern Gulf of St. Lawrence but had direct relevance to the Georges Bank situation. Fisheries developments around 1970 resulted in renewed interest in gear efficiency and selectivity and a further three-year programme was initiated (see below).

The third main area of Canadian scallop research was on the basic biology of the animal. In particular, larval and early settlement stages (spat) of the scallop life history had not been completely identified and described, and this was a prerequisite to understanding the animal's life history and the factors controlling year-class strengths. Substantial efforts were begun in 1960 to collect larvae and spat in Passamaquoddy Bay, and laboratory facilities were set up to induce adult scallops to spawn, and to raise their larvae. Field collections in 1960 were unsuccessful, but laboratory work in 1961 resulted in successful spawning, and larvae were raised for 42 days and their form described. In 1962, field collections again failed but laboratory work produced sufficient larvae for experimental work on food preferences and the effects of temperature on development. Specimens of one group were kept alive for 58 days, by which time they appeared to have reached the settlement stage, although settlement did not occur. This work was continued through 1964 but larval settlement was not achieved, and with a change of staff this approach was terminated. Arrangements were made with the Boothbay Harbor Laboratory of the US Fish and Wildlife Service for a collecting trip to Penobscot Bay, Maine, in March 1966 - an area in which early post-larval stages of sea scallops had previously been reported to occur. This trip was successful, with juvenile scallops being found in abundance. These were epifaunal on the colonial bryozoan, Gemellaria loricata, itself living on the shells of adult scallops. These collections allowed most interesting observations, both in the field and laboratory, on behaviour at this life history stage. Subsequent explorations on both Bay of Fundy and Georges Bank scallop fishing grounds failed to discover similar stages, and the bryozoan, Gemellaria, was found to be of sparse occurrence in these regions. These investigations elucidated various aspects of the early life history of scallops and these results were of general applicability. The failure to locate these stages, and develop effective sampling methods, in areas of commercial fishery importance such as Georges Bank prevented investigations into the factors controlling year-class strengths for these major commercial concentrations. No further work was attempted until after 1980.

The efforts initiated in 1958 to monitor the Canadian commercial fishery, and to provide a basis for interpretation of fisheries data, have been continuous until the present time. Trips on commercial vessels were a common feature in the late 1950's and early 1960's in order to develop a full understanding of commercial practices. The distributional characteristics of scallops presented unique problems in dat[illegible] analysis and received substantial attention. The Cape Eagle expedition of 1961 addressed the spatial variation in scallop density as a secondary objective, and this was also addressed on the A.T. Cameron venture of 1963. The results confirmed the high variances associated with density estimates and gave insights into the sampling intensity required for estimation with particular levels of statistical confidence. A second trip was made on the A.T. Cameron in 1964 to continue the survey work and, in particular, to determine sampling errors, and their implications to the measurement of mortality rates. Survey methods were also being developed, with two types of odometer for measurement of the distance travelled over the bottom by scallop drags being tested in 1964, and with photographic survey methods being evaluated in both 1963 and 1964. A further survey was run on the Harengus in 1966, completing these early efforts directed toward an understanding of the density distribution of scallops as a basis for interpretation of fisheries data and population parameter estimation. They also provided a basis for a new generation of surveys on Georges Bank, designed to provide fishery independent measures of scallop abundance, which were initiated in 1970.

The spur to early Canadian efforts was the rapid expansion of Canadian fishing on Georges Bank and, as a result, expansion of total fishing effort. There was also scientific concern in the early 1960's that there might be a need for fishery controls. The expansion was supported by good recruitment to the exploited stock in 1959-60. The fishery subsequently entered a period of progressive declines in total catch and catch rate and of increase in effective fishing effort. These first research efforts had not resulted in any regulatory controls being introduced, and in the late 1960's Canadian research efforts emphasized work on Canadian inshore scallop resources.

Late in 1969, the Canadian fleet reported that there were appreciable numbers of young scallops to be found on Georges Bank for the first time since 1959-60. The area of their occurence on the northern edge of Georges Bank was surveyed in June 1970 by the E.E. Prince. The survey employed both dredging and photographic methods, and work on gear selectivity was reinitiated. The work was repeated and extended in 1971 and this field and analytical work provided a basis for a detailed analysis of the impact of recent events on the stock. It was clear that fishery concentration on beds of new recruits was detrimental to future yield prospects both from lost yield-per-recruit and high incidental mortality. These results provided the basis for a 1972 Canadian proposal, which was accepted by the ICNAF Fisheries Commission, to limit the size of scallops taken on Georges Bank. Thus, this method of controlling mortality on small scallops received more ready acceptance by fisheries administrators than the indirect method of controlling dredge construction proposed in the early 1960's. It did not receive such ready acceptance by Canadian fishermen, whose stiff opposition resulted in Canada having to lodge an objection to the ICNAF regulation which had been based on its own proposal. The USA followed suit. Canada unilaterally proceeded to phase in a size limit regulation through introduction of progressively lower meat counts, starting at 60 meats/lb in June 1973 and reaching the target of 40 meats/lb in May 1976. (The original proposal to ICNAF was for a restriction to 40 meats/lb and thus Canada was able to withdraw its objection at the June 1976 ICNAF meeting, and the

ICNAF regulation came into effect on 1 September 1976.) By 1977, although Canadian fleet size had been frozen for some time through licence restrictions, further effort controls were considered necessary and vessel catch limits by trip and by four-month period, and trip duration limitations, were introduced for the domestic fishery.

The gear selection work in 1970 and 1971 rekindled Canadian scientific dissatisfaction with the poor selective properties of the offshore dredge and the resultant incidental mortality on unretained scallops. Further gear related research was conducted on Georges Bank by the E.E. Prince in 1972 and 1973 including unsuccessful attempts to test an experimental "box" dredge. The problems proved just as intractable as they had 10 years earlier and no more was done.

The traditional method of ageing scallops is through counts of annual rings on shells but, as only meats are landed, special efforts are required to obtain shell samples representative of the commercial catch. The relationship between individual scallop meat weight and shell height, and its variation with area, was investigated and a method determined to approximate the age composition of the catch based on weight frequency of meats. This was useful in stock assessment. Attention was also given to other ways of increasing yields. Although the entire scallop (except shells) is edible, only the meat (muscle) is harvested. In the late 1970's, substantial collections of roes were made to quantify potential additional yield from roe harvesting by season and area. The implications of a change in harvesting practice have been debated for a much longer period, but concerns over PSP (Paralytic Shellfish Poisoning) have so far prevented change.

It would appear that the Canadian management actions of the early 1970's, which spread out harvesting of the strong year-class observed recruiting to the fishery in 1969, paid off, as landings increased from a low of about 5,000 mt (meats) in 1972 and 1973 to about 11,000 mt in 1976 even though Canadian fishing effort was restricted. However, indications of a possible reversal of the long-term trend of decreasing USA fishing effort, and the climb of total landings to all-time record highs, spurred further Canadian scientific attention. Survey work was reinitiated and extended over a wider area of Georges Bank, using the E.E. Prince, in 1977 and standard surveys have been repeated each year since. Tagging experiments have also been conducted and development of survey techniques has been actively pursued including, in 1980 and 1981, testing the usefulness of the Canadian developed BRUTIV (Bottom Referencing Underwater Towed Instrumented Vehicle) for photographic surveying of scallop beds. Isopleth mapping techniques were developed and applied to commercial catch and effort data to also aid in development of survey design and to develop an understanding of temporal changes in distribution of biomass and productivity.

Although Canada maintained regulatory control of its fishery, the USA fishery expanded in the late 1970's without control and total fishing effort increased greatly. Total landings, however, peaked in 1977 and more recently the Canadian fleet has reverted to a dependence on small, recruit scallops reminiscent of the early 1970's. Canada maintained a level of research activity which allowed Canadian scientists to independently provide a basis for effective regulation of resource exploitation. But, unlike the situation in the early 1970's, the significant USA fishery presence precluded effective unilateral Canadian action prior to the maritime boundary settlement.

Thus, in the 30 years or so that the Canadian fishing industry has participated in the Georges Bank scallop fishery, Canada has mounted a level of fisheries research effort commensurate with this interest. Management initiatives have, to a large extent, been of Canadian origin and based heavily on Canadian research efforts.

Lobsters

Traditionally, lobster fishing was a coastal activity and it was not until 1950 that lobster fishing was extended offshore to Georges Bank by USA fishermen. The first landings were taken mainly as by-catch in finfish otter trawl fisheries but a directed otter trawl fishery gradually developed through the 1950's, and more rapidly in the 1960's. An offshore trap fishery for lobsters was begun in 1969 and this largely replaced the trawl fishery in the early 1970's. The USA Bureau of Commercial Fisheries greatly expanded its lobster research programme in 1964 with emphasis on the possible relationships between inshore and offshore populations and on optimum levels of fishing. Discussions were immediately initiated between USA and Canadian lobster biologists on possible cooperation. Further meetings were held at least annually from 1965 to 1972, and served as a forum for scientific communication and debate, but little if anything in the way of cooperative research projects resulted.

Canadian scientific interest was stimulated, however. In 1965, the Canadian stern trawler, Louise P., was chartered for about a month and a half to conduct exploratory fishing along the edge of the continental shelf from Banquereau to south of Georges Bank. Substantial emphasis was placed on lobster and two trips were directed to Georges Bank. In 1966, the side trawler, P.J. Lawrence, was chartered to extend this research and one trip was directed specifically to trawling for lobsters (and red crab) in an area including Georges Bank. These surveys failed to find sufficient quantities of lobsters along the slope of the Scotian Shelf east of Georges to support a commercial fishery, the only concentrations found being those already known to occur on Georges Bank. Another survey charter was arranged for 1967 on the Albert Riske, this time using lobster traps. Although operations were seriously hampered by hurricanes, 620 trap hauls were made across the northeast section of Georges Bank. Catches were poor and the operation deemed a failure in locating commercial concentrations.

In 1971, Canadian authorities made offshore lobster fishing licences available to swordfish fishermen displaced from the swordfish fishery. As

a result 5-8 offshore trap-fishing vessels have operated each year since 1971. On average, 38% of their catch has been taken from Georges Bank and the rest from Browns Bank. A further trap survey was conducted on Georges Bank in 1972, but the fishery established itself as viable quite quickly and further work of this sort was abandoned. The fishery has been monitored from its inception and log book data have been analyzed to determine variation in catch rates seasonally and by geographic location. Biological sampling of the catch at sea and ashore was initiated in 1976. These data provide a basis for regulatory control of the Canadian fishery.

Life history studies have concentrated on the critical question of stock inter-relationships and, in particular, the relationships between offshore and inshore lobster populations. The movements of the larger benthic stages have been investigated through tagging. During the exploratory fishing ventures of 1965-66, about 200 lobsters were tagged on Browns and Georges banks. The 15 recaptures showed no obvious pattern of movement with the average distance travelled being 25 miles. In 1972-73 a further 642 lobsters were tagged on northeast Georges and southeast Browns banks of which 110 were recovered. All the recoveries were from the offshore fishery and only one lobster moved between the banks from Browns to Georges. In 1975, 1,293 lobsters were tagged on Browns Bank. Of the 198 recovered, six came from Georges Bank.

Another possible inter-relationship between populations could be through drift of larval stages in the plankton, the progeny of one population recruiting to the benthic stages of another. Initial studies were hampered, however, as a result of difficulties in sampling lobster larvae. Plankton sampling was conducted as an adjunct to the 1965-67 and 1972 exploratory fishing but 98 tows on Georges Bank caught only 8 larvae. A further 279 tows on the Scotian Shelf during these same operations caught 4 larvae. The first successful offshore sampling of lobster larvae by Canadians occurred incidentally to finfish egg and larval sampling by the E.E. Prince in 1976, when 142 larvae were taken in the Browns-LaHave banks area, mainly by neuston net. This net samples the surface layer of the water. This stimulated renewed Canadian efforts. These have been primarily directed toward understanding larval movements in the Browns Bank - inshore Nova Scotia area but have also extended to Georges Bank with successful sampling being conducted on Georges Bank in 1977 and 1978. The full results of this work are not yet available.

In summary, Canadian scientific efforts related to Georges Bank lobsters extend from the mid-1960s and preceded Canadian commercial fishing in an exploratory mode. This evolved into a programme of fishery monitoring and studies of stock relationships, elucidation of which is of critical importance to effective resource management.

Red Crab

The deep-sea red crab has been considered a potential candidate for commercial fisheries development for many years, in both the USA and Canada. One of the objectives of the exploratory fishing expedition mounted on the P.J. Lawrence in 1966 was the red crab resources on the slopes of the Scotian Shelf and Georges Bank. In the 1969-71 period the Nova Scotia Provincial Department of Fisheries followed up with exploratory fishing of their own on the Scotian Shelf. In 1978, Canadian Federal authorities again mounted an offshore exploratory survey using a chartered vessel and operated in the area from Sable Island to Georges Bank, this time using traps. This exploratory work has not resulted in any sustained Canadian commercial fishery development to date. Exploratory fishing results to the south of the areas covered by Canadian efforts have been rather more encouraging and a small sustained USA fishery has been developed from Georges Bank south in the 1970's.

Squid

Prior to about 1970 the largest squid fishery in the northwest Atlantic was conducted during the summer in Newfoundland coastal waters. Squid were caught by jigging and used primarily for bait. This fishery exploited the short-finned squid, Illex illecebrosus, during its summer feeding phase and landings varied with its availability in inshore waters. (Maximum recorded catch from inshore Newfoundland areas in the period 1955-75 was 10,000 mt in 1964.)

To investigate the life history and distribution of the species during other seasons, three expeditions were mounted on the A.T. Cameron in southern waters. The first of these took place in March-April of 1967 and involved otter trawl sampling along the continental slope between LaHave Bank and Cape Hatteras. The second was in August-September 1968 and concentrated in the Mid-Atlantic Bight. The third occurred in February 1969 and covered the continental slope from Delaware Bay to off Fort Pierce in Florida. The substantial amount of information generated on Illex and associated species provided useful insights into their distribution and biology. These cruises did not locate the spawning grounds of Illex, however, which was a matter of substantial interest and potential practical importance.

Substantial fisheries developed for squid in the northwest Atlantic about 1970. These started in Subareas 5-6 with concentration on the long-finned squid, Loligo pealei, a species with a northern limit at the southern edge of Georges Bank. Interest quickly spread to the less valued Illex, and landings increased rapidly from 1972 in Subareas 5-6 and from 1975 in Subareas 3-4, peaking at 180,000 mt from the Northwest Atlantic in 1979. It is now apparent that the potential yield of Illex in terms of tonnage is substantially higher than that of Loligo, and the centre of Illex population biomass in summer months is substantially further north. The relationship of these northern Illex populations with that on Georges Bank is still unknown.

Canada has conducted a substantial amount of research, and promoted and coordinated large-scale international cooperative research efforts, on squid ecology and fisheries in Subareas 3 and 4. This

research relating to resource ecology and resource management is, in many aspects, relevant to the resource as a whole. One cooperative research venture between Canada and France extended into Subarea 5 in May and November-December 1975 when broad-scale seasonal surveys were conducted aboard the French research vessel Cryos. Another, and larger scale, effort involved Canada-USSR cooperative winter surveys south of the continental shelf to the Gulf Stream and Sargasso Sea, in search of the Illex spawning grounds and to describe the quantitative distribution of eggs and larvae. The first operation by the USSR research vessel Belogorsk in February-May 1979 was successful in locating larvae and juveniles in the Slope Water bordering the Gulf Stream. Further operations were conducted by USSR and Canadian vessels in the 1980-81 winter season. This research will hopefully provide a basis for understanding the reasons for variations in Illex year-class strength and through this, a basis for prediction of fishery success. This is critically important for this species as the fishery in each year is based entirely on recruitment in that year. This research could also clarify the relationship of Georges Bank squid to those found to the north. Canada has also conducted a substantial amount of laboratory research on Illex complementary to the large-scale field programmes. This has provided knowledge on the temperature range for spawning, the nature of the egg mass, the identifying characteristics of eggs and larvae, larval survivorship in relation to temperature, and various aspects of squid behaviour.

Oceanography

Oceanographic observations taken by Canada in NAFO Subarea 5 have most commonly been associated with fisheries research, since the physical environment is generally considered an important variable in determining distribution and year-class strengths. At times, however, observations have been taken as part of general environmental studies of the Atlantic continental shelf, or as part of special applied needs such as knowledge of the tidal regime and how it might change in the Georges Bank - Gulf of Maine area should tidal power barrages be installed in the Bay of Fundy.

Relatively little oceanographic research was done in the Gulf of Maine Area prior to 1950 although the drift bottle release programme in the Bay of Fundy and off southwestern Nova Scotia in the 1920's is a notable exception. These releases by the St. Andrews Biological Station, combined with releases in the Gulf of Maine by USA investigators, allowed H.B. Bigelow (1927) of Harvard University to develop a picture of the surface circulation pattern for the entire Gulf of Maine - Georges Bank - Bay of Fundy area which, after more than half a century of additional studies, remains valid in most respects.

After the Second World War the Atlantic Oceanographic Group located at the St. Andrews Biological Station commenced an oceanographic monitoring programme consisting of seasonal occupation of a network of stations covering the Gulf of St. Lawrence, Scotian Shelf and Bay of Fundy, and this included stations on Browns Bank, across Northeast Channel and onto the eastern part of Georges Bank. Although ice prevented occupations of stations in the Gulf of St. Lawrence in winter, and an occasional season was missed in the southern part of the area owing to a ship not being available, the network was consistently surveyed over a period of 10 years.

A great deal of cooperative research between Canada and the USA was required in the 1956-59 period in relation to the work of the International Passamaquoddy Fisheries Board on the impact of proposed tidal power dams on fisheries. These investigations stretched out from Passamaquoddy Bay to include most of the Bay of Fundy, Gulf of Maine and Georges Bank. The use of drift bottles to infer surface circulation, a method not much used since the 1920's, regained popularity in the 1950's, and was used extensively in the 1956-59 investigations. Drift bottles were also used in investigations on the Scotian Shelf (in 1954) and in the eastern Gulf of Maine and on eastern Georges Bank (in 1957) by the Defence Research Board of Canada.

To some extent in the 1950's, and to an increasing extent in the 1960's, oceanographic observations became a routine ancillary to fisheries research cruises and this has continued since. Some operations gave oceanography a higher profile, the 1967-70 cruise series of herring larval surveys being a case in point where the entire cruise series was conducted jointly by oceanographers and herring biologists as equal partners. These and some other cruises in this same general area, particularly the herring larval cruises in the Bay of Fundy in 1972-74, released substantial numbers of surface and sea bed drifters as part of an Atlantic coast programme operated out of St. Andrews.

In the latter half of the 1970's the prospect of tidal power development arose yet again but this time at the head of the Bay of Fundy and thus in a purely Canadian context. The need to understand the tidal regime throughout the entire Bay of Fundy - Gulf of Maine - Georges Bank area became critical to feasibility studies for this development. Superimposed on these needs was an increasing interest in the non-renewable resource potential of the continental shelf along the entire eastern seaboard of both the USA and Canada. In 1976, as part of the study of the tidal system, submerged tide guages were moored at 8 sites in the Gulf of Maine, along the southeast side of Georges Bank and on Nantucket Shoals for periods varying from one to three months. A current meter mooring was also installed off the southeastern edge of Georges Bank.

The ICNAF sponsored international study on the factors controlling year-class strengths in fishes focused on the Georges Bank - Gulf of Maine herring, expanding previously ongoing studies. A major process-oriented study of a herring larval patch was planned which would determine and measure the physical and biological process influencing their movement, dispersion, growth and survival. Canada contributed substantially to the planning of this operation in 1975 and 1976 and, in 1977, participated in pilot experiments for a major at-sea programme in 1978. The Canadian oceanographic research ship Dawson visited Georges Bank in September 1977 to make preliminary measurements of

larval herring patchiness, dispersion characteristics and oceanographic structure on the northern edge of the bank. One hundred and ten oceanographic stations were occupied within the Georges Bank study area, a 25-hr current meter profiling station was completed, diffusion measurements were made with rhodamine dye, and detailed plankton transects were run. Further preparatory work was done in this area in November 1977 on the fisheries research vessel E.E. Prince. In October-November 1978 the major experiment was undertaken. The oceanographic ship Dawson spent close to a month on Georges Bank accompanied by the two fisheries vessels Lady Hammond and Canso Condor. Five ships from other nations participated. The Dawson collected measurements from current meters moored at 3 sites during the experiment, obtained over 500 salinity and temperature profiles, and conducted drogue deployments, dye diffusion measurements, and vertical and horizontal measurements of zooplankton structure.

Also in the 1970s, investigation of the relationship between the environment and marine production demonstrated for a range of fish stocks along the Canadian Atlantic continental shelf, including those in the Gulf of Maine Area, that there were strong correlations between selected environmental signals and subsequent stock abundance. The effects of the freshwater discharged from the St. Lawrence river system were traced by correlation analysis from the Gulf of St. Lawrence, along the Scotian Shelf, and through the Gulf of Maine. Catches of ten of 17 commercially important species of fish and shellfish from the Gulf of Maine were significantly correlated with local environmental features. This work illustrated that environmentally imposed patterns underlie at least 50% of the variability in catch, and also illustrated possible linkages between fishery yields in the Gulf of Maine and such distant events as variability in St. Lawrence river runoff.

Concluding Remarks

Canada's research efforts on Georges Bank have been commensurate with her fisheries interest in the resources of the area. Div. 4X- Subarea 5 has been the area in which the major Canadian research efforts on scallops, herring and large pelagic fishes have been focused. Although Canada's groundfish efforts have concentrated in more easterly areas and are outweighed on Georges Bank by those of the USA, Canada has made a longstanding, continuing and significant contribution to groundfish research in the area.

A primary motivation for support of applied fisheries research, in the case of international fisheries, is the protection of national interest. Since regulatory measures have traditionally had a scientific basis, national fisheries negotiators need to be aware of the potential impact of proposed regulatory measures on their domestic fisheries. Conversely, they need to be aware of the impacts of foreign fishing practices on domestic fishery prospects, and of the relative values of potential regulatory measures to ameliorate adverse effects. The notion of responsibility is also common and was used, for example, as justification of a substantial research programme on large pelagic fish. It was felt to be incumbent on Canada, as the major exploiter (at that time), to provide a basis for rational management. These various motivations, along with exploratory fishing expeditions to assess the potential for fisheries development and the occasional indulgence of straightforward scientific interest, have interwoven to provide the pattern of activities on Georges Bank outlined in previous sections.

The 90-100 documentable cases of Canadian research or charter vessel occupations of Georges Bank (Appendix 2; see also Appendices 3 and 4) provide a crude indicator of the level of Canadian research interest. Some of these occupations were fleeting and the data collected of limited value, while others were major operations, the results of which have provided the basis for critically important management actions or generated significant scientific knowledge. This list does not reflect activities in adjacent areas of indirect importance to understanding the biology of resources on Georges Bank. A listing of scientific publications by Canadian authors perhaps provides a clearer impression of the extent of the Canadian contribution to knowledge of Georges Bank resources. Over 150 relevant scientific papers have been located (Appendix 1), many of which represent major contributions to the scientific literature. These do not represent the full intellectual contribution of Canadian scientists to Georges Bank fisheries science and management: throughout the history of fisheries research in this area, the continuing intensive collaboration between USA and Canadian scientists is striking. Meetings, debates, controversies, joint data collection, analysis, publication, and data exchanges, are legion and, while Canadian contributions through these to resolution of the management problems on Georges Bank cannot be quantified, they were undoubtedly of substantial importance.

Acknowledgements

The practical and financial arrangements for this work were made by J.E. Stewart, Director, Fisheries Research Branch, Scotia-Fundy Region of the Atlantic Fisheries Service. The facilities of the Biological Station, St. Andrews, N.B., particularly those of the library, were made fully available and the help of the Librarian, Ruth Garnett, is acknowledged in particular. The present and past staff of the St. Andrews Biological Station who contributed from their memories or their files are too numerous to mention individually but their help is none the less appreciated. The aid of R. Chandler and P. Hurley, who extracted large amounts of material from historical files, was essential to completion of the project and their timely efforts are gratefully acknowledged. Our thanks are extended to the following who read and provided comments on an earlier text, or parts of it: T. Amaratunga, J. Beckett, R. Chandler, P. Hurley, T.D. Iles, G. Jamieson, D. Pezzack, G. Robert, T. Rowell, M. Sinclair, A. Stasko, W. Stobo. We are especially grateful to J. Scott and J. Beckett for their review, and helpful suggestions for improvement, of this report.

Selected Bibliography

This bibliography provides the reference for these few papers cited in the main text and also a listing of the most important of the series of source documents used.

Beverton, R.J.H. and V.M. Hodder (eds.). 1962. Report of the working group of scientists on fishery assessment in relation to regulatory problems. Supplement to ICNAF Annual Proceedings Vol. 11, 81 pp.

Bigelow, H.B. 1927. Physical oceanography of the Gulf of Maine. Bull. U.S. Bur. Fish., 40(2), Doc. 969, 1027 pp.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fishery Bulletin No. 74 (Vol. 53), 577 pp.

Fisheries Research Board of Canada
- Annual Reports of the Biological Station, St. Andrews, N.B., 1945-75.
- St. Andrews Biological Station Original Manuscript Series (locally- indexed unpublished reports).

Hart, J.L. 1958. Fisheries Research Board of Canada Biological Station, St. Andrews, N.B., 1908-1958. Fifty years of research in aquatic biology. J. Fish. Res. Bd. Canada, 15: 1127-1161.

International Commission for Northwest Atlantic Fisheries
- Annual Reports (Proceedings) Vol. 1-29, 1951-80. (Proceedings of the Commission also issued separately for 13th Annual Meeting 1963 and subsequently.)
- Reports of the Standing Committee on Research and Statistics (ICNAF Redbooks), 1958-79.
- Meeting Documents (subsequently issued as Research, Summary, and Commission, document series).

International Passamaquoddy Fisheries Board
- Passamaquoddy Fisheries Investigations, 1957-58. Report to the International Joint Commission (1960). U.S. Fish. Wildlife Serv., Spec. Sci. Rept. - Fisheries, No. 360, 40 pp. (Intern. Passamaquoddy Fish. Bd. 1956-59, Sci. Rept. No. 2).
- Hart, J.L. and D.L. McKernan. 1960. International Passamaquoddy Fisheries Board fisheries investigations 1956-59. Introductory account. J. Fish. Res. Bd. Canada, 17: 127-131.

Northwest Atlantic Fisheries Organization
- Scientific Council Reports (NAFO Redbooks), 1980 (and subsequent).

Appendix 1

RESEARCH REPORTS RELATED TO NAFO SUBAREA 5 AND 6 MATTERS PUBLISHED BY CANADIAN RESEARCH WORKERS

Anthony, V.C. and J.F. Caddy, (eds.). 1980. Proceedings of the Canada-US workshop on the status of assessment science for N.W. Atlantic lobster (Homarus americanus) stocks (St. Andrews, N.B., Oct. 24-26, 1978). Can. Tech. Rept. Fish Aquat. Sci. 932: 186 p.

Beamish, F.W.H. 1966. Vertical migration by demersal fish in the Northwest Atlantic. J. Fish. Res. Bd., Canada, 23: 109-139.

Beckett, J.S. 1968. A harpoon adapter for tagging large free-swimming fish at the surface. J. Fish. Res. Bd. Canada 25 (1): 177-179.

Beckett, J.S. 1968. Longline lures for swordfish. Fish. Can. 21 (5): 26-27.

Beckett, J.S. 1968. New records of the barnacle Conchoderma virgatum in the northwest Atlantic. J. Fish. Res. Bd., Canada, 25: 2707-2710.

Beckett, J.S. and S.N. Tibbo. 1968. Recent changes in the size composition of Canadian swordfish catches. ICNAF Res. Doc. 68/69, Ser. No. 2056. (Also published in ICNAF Redbook 1968 (III): 62-66.)

Beckett, J.S. 1970. Swordfish, shark, and tuna tagging 1961-69. Fish. Res. Bd., Canada, Tech. Rept. No 193, 13 pp + 8 fig. + 7 tables.

Beckett, J.S. 1971. Canadian swordfish longline fishery. ICCAT Doc. SCRS 71/36, 14 pp.

Beckett, J.S. 1974. High recovery rates of small bluefin tuna (Thunnus thynnus L.) tagged in the Northwest Atlantic. ICCAT Col. Vol. Sci. Pap. II: 232-233. (Also ICCAT SCRS/73/44.)

Beckett, J.S. 1974. Biology of swordfish, Xiphias gladius L., in the northwest Atlantic Ocean. NOAA Tech. Rep. NMFS SSRF-675. In "Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972". Part 2. Review and Contributed Papers. Richard S. Shomura and Francis Williams (Editors), pp. 103-106.

Beckett, J.S. and H.C. Freeman. 1974. Mercury in swordfish and other pelagic species from the western Atlantic Ocean. NOAA Tech. Rept. NMFS SSRF-675. In "Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972". Part 2. Review and Contributed Papers. Richard S. Shomura and Francis Williams (Editors), pp. 154-159.

Beckett, J.S., W.T. Stobo, and C.A. Dickson. 1974. Southwesterly migration of Atlantic mackerel, Scomber scombrus, tagged off Nova Scotia. ICNAF Res. Doc. 74/94, Ser. No. 3330.

Belzile, L. 1978. Report on the discarding of fish in the Canadian offshore fishery in ICNAF Subareas 4 and 5. ICNAF Res. Doc. 78/83, Ser. No. 5293.

Bourne, N. 1960. Selection of Georges Bank scallops by Canadian draggers. ICNAF Redbook 1960: 62-65.

Bourne, N. 1960. Outlook for the Georges Bank scallop fishery. Fish. Res. Bd. Canada, Biol. Sta., St. Andrews, Circular, General Series, No. 33, 2 pp.

Bourne, N. 1962. Offshore scallop gear research. ICNAF Meeting Doc. 62/56, Ser. No. 999.

Bourne, N. 1964. Scallops and the offshore fishery of the Maritimes. Bull. Fish. Res. Bd., Canada, No. 145, 60 pp.

Bourne, N., E. Cadima and J.E. Paloheimo. 1964. Studies on Georges Bank sea scallop abundance and distribution. ICNAF Res. Doc. 64/65, Ser. No. 1361.

Bourne, N. 1965. A comparison of catches by 3- and 4-inch rings on offshore scallop drags. J. Fish. Res. Bd., Canada, 22: 313-333.

Bourne, N. 1965. Paralytic shellfish poison in sea scallops (Placopecten magellanicus Gmelin). J. Fish. Res. Bd., Canada, 22: 1137-1149.

Bourne, N. and E.G. Bligh. 1965. Orange-red meats in sea scallops. J. Fish. Res. Bd. Canada, 22: 861-4.

Bourne, N. and F.C. Read. 1965. Fuller utilization of sea scallops (Placopecten magellanicus, Gmelin). Fish. Res. Bd. Canada, Man. Rept. No. 806.

Bourne, N. 1966. Relative fishing efficiency and selection of three types of scallop drags. ICNAF Res. Bull. No. 3: 15-25.

Bourne, N. and T. Rowell. 1966. A comparison of two types of odometers. Fish. Res. Bd. Canada, MS Rept. Biol., No. 888, 14 pp.

Bumpus, D.F. and L.M. Lauzier. 1965. Surface circulation on the Continental Shelf - off eastern North America between Newfoundland and Florida. American Geographical Society Ser. Atlas Mar. Environment, Folio 7.

Caddy, J.F. 1968. Underwater observations on scallop (Placopecten magellanicus) behaviour and drag efficiency. J. Fish. Res. Bd. Canada, 25 (10): 2123-2141.

Caddy, and E.I. Lord. 1968. Recent developments in Georges Bank scallop fishery. ICNAF Res. Doc. 68/59, Ser. No. 2040. (Also published in ICNAF Redbook 1968 (III): 89-93.)

Caddy, J.F. and R.A. Chandler. 1969. Georges Bank survey, August 1966: a preliminary study of the relationship between research vessel catch, depth and commercial effort. Fish. Res. Bd. Canada, MS Rept. No. 1054, 15 pp.

Caddy, J.F. 1971. Recent scallop recruitment and apparent reduction in cull size by the Canadian fleet on Georges Bank. ICNAF Res. Doc. 71/84, Ser. No. 2552. (Also published in ICNAF Redbook 1971 (III): 147-155.)

Caddy, J.F. 1971. Efficiency and selectivity of the Canadian offshore scallop dredge. ICES C.M. 1971/K:25, 8 pp.

Caddy, J.F. and E.I. Lord. 1971. High price of scallop landings conceals decline in offshore stocks. Fish. Can. 23(5): 3-7.

Caddy, J.F. and A. Sreedharan. 1971. The effect of recent recruitment to the Georges Bank scallop fishery on meat sizes landed by the offshore fleet in the summer of 1970. Fish. Res. Bd., Canada, Tech. Rept. No. 256, 11 pp + 3 tables + 3 app. + 9 fig.

Caddy, J.F., J.J. Graham, T.D. Iles, A.M. Pankratov, I.K. Sigajev, and S.B. Chenoweth. 1971. A preliminary report on the combined USSR, USA and Canadian surface ship and submersible study of herring spawning grounds, Georges Bank, 1970. ICNAF Res. Doc. 71/85, Ser. No. 2554. (Revised version published as several papers in NAFO Res. Bull. No. 10.)

Caddy, J.F. 1972. Size selectivity of the Georges Bank offshore dredge and mortality estimate for scallops from the northern edge of Georges in the period June 1970 to 1971. ICNAF Res. Doc. 72/5, Ser. No. 2688. (Also published in ICNAF Redbook 1972 (III): 79-86.)

Caddy, J.F. 1972. Some recommendations for conservation of Georges Bank scallop stocks. ICNAF Res. Doc. 72/6, Ser. No. 2689.

Caddy, J.F. 1972. Progressive loss of byssal attachment with size in the sea scallop, Placopecten magellanicus (Gmelin). J. Exp. Mar. Biol. Ecol. 9: 179-190.

Caddy, J.F. and C. Radley-Walters. 1972. Estimating count per pound of scallop meats by volumetric measurement. Fish. Res. Bd. Canada, MS Rept. No. 1202, 9 pp.

Caddy, J.F. 1973. Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. J. Fish. Res. Bd. Canada, 30: 173-180.

Caddy, J.F. and T.D. Iles. 1973. Underwater observations on herring spawning grounds on Georges Bank. ICNAF Res. Bull. No 10: 131-140.

Caddy, J.F. 1975. Spatial model for an exploited shellfish population, and its application to the Georges Bank scallop fishery. J. Fish Res. Bd., Canada 32: 1305-1328.

Caddy, J.F. 1975. Cohort analysis of Atlantic bluefin tuna and estimates of escapement through the juvenile fisheries under two hypotheses of catch age structure. ICCAT Col. Vol. Sci. Pap. IV: 186-197. (Also ICCAT SCRS/74/52.)

Caddy, J.F., R. Francis, A. Laurec and W.H. Lenarz. 1975. Projected effects of different levels of overall mortality on long-term yield from Atlantic bluefin tuna fisheries. ICCAT Col. Vol. Sci. Pap. IV: 173-176. (Also ICCAT SCRS/74/59 Rev.)

Caddy, J.F. 1976. A review of some factors relevant to management of swordfish fisheries in the northwest Atlantic. Can. Fish. and Mar. Serv., Tech. Rept. No. 633, 36 pp.

Caddy, J.F. 1977. Some approaches to elucidation of the dynamics of swordfish (Xiphias gladius) populations. Fish. Res. Bd., Canada, Man. Rept. No. 1439, 10 pp.

Caddy, J.F. 1977. CAFSAC invertebrate and marine plants background data for CAFSAC Invertebrate and Marine Plants Subcommittee. CAFSAC Res. Doc. 77/18.

Caddy, J.F. and G.S. Jamieson. 1977. Assessment of Georges Bank (ICNAF Subdivision 5Ze) scallop stock 1972-76 incorporated. CAFSAC Res. Doc. 77/32.

Carrothers, P.J.G. 1974. Descriptions of trawl-gear used for demersal species by the Canadian fleet in Subarea 5 and Statistical Area 6 during the period 1969 through 1972. ICNAF Res. Doc. 74/28, Ser. No. 3175.

Chandler, R.A. 1970. Ancient shark teeth. Fish. Can. 22 (7): 17-18.

Chandler, R.A. and J.C. Medcof. 1969. A "catch" 20 million years old. Fish. Can. 21(8): 15-16. (Also published as: Strange catches - "stones with holes in". Young Naturalist 11(8): 3.)

Clark, J.R., F.D. McCracken, and W. Templeman. 1958. Summary of gear selection information for the Commission Area. ICNAF Annu. Proc. Vol. 8: 83-99.

Clark, S.H., T. Burns and R.G. Halliday. 1976. A preliminary assessment of the pollock fishery in ICNAF Divisions 4VWX and Subarea 5. ICNAF Res. Doc. 76/47, Ser. No. 3833. (Also published in ICNAF Sel. Papers No. 2: 15-32.)

Clark, S., T. Burns, and R.G. Halliday. 1977. Pollock in Divisions 4VWX and Subarea 5. CAFSAC Res. Doc. 77/9.

Cleary, L. 1978. An assessment of 4VWX + 5 pollock. CAFSAC Res. Doc. 78/24 + addendum.

Cleary, L. 1980. Assessment of 4VWX5-6 pollock. CAFSAC Res. Doc. 80/1.

Das, N. 1968. Spawning, distribution, survival and growth of larval herring (Clupea harengus L.) in relation to hydrographic conditions in the Bay of Fundy. Fish. Res. Bd., Canada, Tech. Rept. No. 88, 129 pp + 27 Fig.

Das, N. 1972. Growth of larval herring in the Bay of Fundy and Gulf of Maine area. J. Fish. Res. Bd., Canada, 29: 573-575.

DeWolfe, D.L. 1977. Tidal measurement program in the Bay of Fundy-Gulf of Maine Tidal Regime. Canadian Hydrographic Association "Lighthouse" 15, pp 17-24.

Dickie, L.M. and J.C. Medcof. 1956. Environment and the scallop fishery. Can. Fisherman, 43(9): 7-9.

Dickie, L.M. 1958. Role of study boats using small-mesh nets in assessing effects of the Georges Bank haddock regulation. ICNAF Res. Doc. 58/17, Ser. No. 543.

Dickie, L.M. 1958. Recent trends in the scallop fishery of eastern Canada. Fish. Res. Bd. Canada, Atl. Prog. Rept. No. 70, pp. 31-34.

Dornheim, H., T.D. Iles, and M.D. Grosslein. 1973. A Preliminary report on the German young herring survey carried out by R/V Walther Herwig in ICNAF Subarea 5 and Statistical Area 6 in February - March 1973 + Addenda 1 and 2. ICNAF Res. Doc. 73/84, Ser. No. 3036.

Doubleday, W.G. 1976. Report of special sampling project for cod in Divisions 2J+3KL, mackerel in Subareas 3-5 and Statistical Area 6, and silver hake in Subareas 4-5 and Statistical Area 6. ICNAF Res. Doc. 76/100, Ser. No. 3922.

Drapeau, G. 1973. Sedimentology of herring spawning grounds on Georges Bank. ICNAF Res. Bull. No. 10: 151-162.

Garrett, C. 1972. Tidal resonance in the Bay of Fundy and Gulf of Maine. Nature, Vol. 238 (Aug): 441-443.

Garrett, C. 1974. Normal modes of the Bay of Fundy and Gulf of Maine. Can. J. Earth Sci. Vol. 11, No. 4: 549-556.

Garrett, C.J.R., J.R. Keeley and D.A. Greenberg. 1978. Tidal mixing versus thermal stratification in the Bay of Fundy and Gulf of Maine. Atmosphere- Ocean 16(4): 403-423.

Gran, H.H. and T. Braarud. 1935. A quantitative study of the phytoplankton in the Bay of Fundy and the Gulf of Maine (including observations on hydrography, chemistry and turbidity). J. Biol. Bd. Canada, 1: 279-467.

Graham, M. 1936. Investigations of the herring of Passamaquoddy Bay and adjacent regions. J. Biol. Bd. Canada, 2: 95-140.

Greenberg, D.A. 1979. A numerical model investigation of tidal phenomena in the Bay of Fundy and Gulf of Maine, Marine Geodesy, Vol. 2, No. 2: 161-187.

Hachey, H.B., F. Hermann and W.B. Bailey. 1954. The waters of the ICNAF Convention Area. ICNAF Annu. Proc. for 1953-54, Vol. 4: 67-102.

Hachey, H.B. 1961. Oceanography and Canadian Atlantic waters. Fish. Res. Board of Can. Bull. No. 134, 120 pp.

Halliday, R.G. 1974. A review of the biology of the Atlantic argentine with particular reference to the Scotian Shelf. ICNAF Res. Doc. 74/21, Ser. No. 3168.

Halliday, R.G. 1974. A description of Canadian fisheries in Subarea 5 and Statistical Area 6, 1969-72. ICNAF Res. Doc. 74/27, Ser. No. 3174.

Halliday, R.G. and F.D. McCracken. 1970. Movements of haddock tagged off Digby, Nova Scotia. ICNAF Res. Bull. No. 7: 8-14.

Hare, G.M. 1977. Atlas of the major Atlantic coast fish and invertebrate resources adjacent to the Canada - United States boundary areas. Fish. Res. Bd., Canada, Tech. Rept. No. 681, 97 pp.

Humphreys, R.D. 1966. Canadian research on the biology of the Bay of Fundy - Gulf of Maine herring populations. Can. Fish. Rept. 8: 21-37.

Hunt, J.J. 1974. Comparison of the otolith length/width ratio of herring in ICNAF Subareas 4 and 5. ICNAF Res. Doc. 74/93, Ser. No. 3329.

Hurley, P.C.F. and T.D.Iles. 1980. A review of the Canadian swordfish fishery. CAFSAC Res. Doc. 80/81. (Also ICCAT SCRS/80/48 Rev.)

Iles, C. 1971. Fistulicola plicatus (Cestoda) and Tristoma spp. (Trematoda) on swordfish from the northwest Atlantic. J. Fish. Res. Bd., Canada, 28: 31-34.

Iles, T.D. 1970. Vertebral numbers of the Bay of Fundy herring and the origin of New Brunswick sardines. ICNAF Res. Doc. 70/82, Ser. No. 2431. (Also published in ICNAF Redbook 1970 (III): 148-151.)

Iles. T.D. and J.F. Caddy. 1972. Herring spawn in close-up. World Fishing, June 1972: 14-16.

Iles, T.D. and C.H. Hatt. 1980. Unsolved and open questions concerning the recruitment of herring in the Northwest Atlantic. NAFO SCR Doc. 80/IX/142, Ser. No. N216.

Jamieson, G.S. and R. Chandler. 1980. The potential for research and fishery performance data isopleths in population assessment of offshore, sedentary, contagiously distributed species. CAFSAC Res. Doc. 80/77.

Jones, C. 1978. Standardization of Canadian east coast statistical Unit Areas. CAFSAC Res. Doc. 78/32 (revised).

Keeley, J.R. 1980. Marine Environmental Data Service Progress report for 1979-1980. NAFO SCR Doc. 80/IX/149, Ser. No. N223.

Keeley, J.R. 1980. An inventory of the physical/chemical data for the Georges Bank larval herring study, 1971-77. NAFO SCR Doc. 80/IX/148, Ser. No. N222.

Kohler, A.C. and J.R. Clark. 1958. Haddock scale-otolith comparisons. J. Fish. Res. Bd. Canada, 15: 1239-1246.

Kohler, A.C. 1969. Cod and haddock catches from Georges Bank, the Bay of Fundy, Scotian Shelf, and the Gulf of St. Lawrence by Maritime otter trawlers in 1967. Fish. Res. Bd., Canada, Tech. Rept. No. 157, 4 pp + 1 table + 25 fig.

Kulka, D.W. 1977. An hypothesis concerning the migration and distribution of Atlantic mackerel (Scomber scombrus). CAFSAC Res. Doc. 77/7.

Lenarz, W.H., F.J. Mather III, J. Beckett, A.C. Jones and J. Mason. 1973. Estimation of rates of tag shedding of northwest Atlantic bluefin tuna. ICCAT Col. Vol. Sci. Pap. I: 459-472. (Also ICCAT SCRS/72/25.)

Lett, P.F., and W.H. Marshall. 1978. An interpretation of biological factors important in the management of the northwestern Atlantic mackerel stock. CAFSAC Res. Doc. 78/17.

Lett, P.F., W.T. Stobo, and W.G. Doubleday. 1975. A system simulation of the Atlantic mackerel fishery in ICNAF Subareas 3, 4 and 5, and Statistical Area 6, with special reference to stock management. ICNAF Res. Doc. 75/32, Ser. No. 3511.

Loder, J. 1980. Tidal rectification on Georges Bank. J. Phys. Oceanogr. 10(9): 1399-1416.

Lord, E.I. and R.A. Chandler. 1969. Whale skulls from Georges Bank. Fish. Can. 22(1): 17-18.

MacKay, K.T. and E.T. Garside. 1969. Meristic analysis of Atlantic mackerel, Scomber scombrus, from the North American coastal populations. J. Fish. Res. Bd., Canada, 26: 2537-2540.

Maguire, J.J. 1979. An analytical assessment of SA3-6 mackerel with information from egg and larval survey. CAFSAC Res. Doc. 79/46.

Maguire, J.J. 1980. An analytical assessment of mackerel in NAFO SA3-6. CAFSAC Res. Doc. 80/65.

Markle, Gretchen E. 1974. Distribution of larval swordfish in the N.W. Atlantic. Fish. Res. Bd., Canada, MS Rept. Ser. No. 1305, 13 pp. (Also published in: NOAA Tech. Rep. NMFS SSRF-675. "Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972". Part 2. Review and Contributed Papers. Richard S. Shomura and Francis Williams (Editors), pp. 252-260.)

Martin, W.R. and A.C. Kohler. 1965. Variation in recruitment of cod (Gadus morhua L.) in southern ICNAF waters, as related to environmental changes. ICNAF Spec. Publ. No. 6: 883-846.

Mather, III, F.J., M.R. Bartlett and J.S. Beckett. 1967. Transatlantic migrations of young bluefin tuna. J. Fish. Res. Bd., Canada, 24: 1991-1997.

Mavor, J. W. 1922. The circulation of the water in the Bay of Fundy. I. Introduction and drift bottle experiments. Contr. Canadian Biol. N.S., 1 (8): 101-124.

McCracken, F.D. 1956. Cod and haddock tagging off Lockeport, N.S. Fish. Res. Bd. Canada, Atl. Prog. Rept. No. 64: 10-15.

McCracken, F.D. 1960. Studies of haddock in the Passamaquoddy Bay region. J. Fish. Res. Bd. Canada, 17 (2): 175-180.

McCracken, F.D. 1968. Cod and haddock catches by Maritime trawlers on the Scotian Shelf and Georges Bank, 1965. Fish. Res. Bd., Canada, Tech. Rept. No. 86, 3 pp + 25 fig.

McCracken, F.D. 1972. Status of the fisheries and research carried out in Subarea 5 in 1971. ICNAF Res. Doc. 72/129, Ser. No. 2860. (Also published in ICNAF Annu. Proc. Vol. 22: 90-93.)

McKenzie, R.A. and S.N. Tibbo. 1961. Herring movements in the Bay of Fundy and the Gulf of Maine, 1957 and 1958. J. Fish. Res. Bd. Canada, 18, (2): 221-252.

McKenzie, R.A. and S.N. Tibbo. 1964. A morphometric description of blue shark (Prionace glauca) from Canadian Atlantic waters. J. Fish. Res. Bd. Canada, 21: 865-866.

McKenzie, R.A. 1966. Offshore exploratory fishing (argentine, silver hake) July-Aug. 1965. Fish. Res. Bd. Canada, MS Rept. Biol. No. 863, 74 pp.

McKenzie, R.A. 1966. Canadian Atlantic offshore lobster and red crab investigations, 1966. Fish. Res. Bd., Canada, Man. Rept. No. 895, 34 pp.

McKenzie, R.A. 1966. Canadian Atlantic offshore exploratory fishing, 1966. Fish. Res. Bd., Canada, Man. Rept. No. 913, 9 pp.

McKenzie, R.A. 1966. Offshore lobster investigations, 1965. Can. Fish. Rep. 6: 4-32.

McKenzie, R.A. 1967. Fawn cusk-eel, Lepophidium cervinum, in the Northwest Atlantic. J. Fish. Res. Bd. Canada, 24: 213-214.

McLellan, H.J. 1955. Studies of slope water east of Georges Bank. M.S. Rept. Atl. Biol. Stn. No. 619, 126 pp.

Medcof, J.C. and N. Bourne. 1964. Causes of mortality of the sea scallop, P. magellanicus. Proc. Natl. Shellfish Assoc., 53: 33-50.

Medcof, J.C., A.H. Clarke Jr. and J.S. Erskine. 1965. Ancient Canadian east-coast oyster and quahaug shells. J. Fish. Res. Bd., Canada, 22: 631-634.

Medcof, J.C. and E.I. Lord. 1968. Strange catch - a walrus tusk. Fish. Can. 21(3): 19-20.

MEDS, Ottawa, Canada. 1976. Monthly distributions of oceanographic stations in the ICNAF Area, 1950-59. ICNAF Res. Doc. 76/5, Ser. No. 3769.

MEDS, Ottawa, Canada. 1976. Monthly summaries of oceanographic stations in the ICNAF Area, 1950-73. ICNAF Res. Doc. 76/6, Ser. No. 3770.

Mercer, M.C. 1969. A.T. Cameron Cruise 130, otter-trawl survey from southern Nova Scotia to Cape Hatteras, March-April 1967. Fish. Res. Bd., Canada, Tech. Rept. No. 103, 24 pp.

Mercer, M.C. 1969. A.T. Cameron Cruise 150, otter-trawl survey of the Mid-Atlantic Bight, August-September 1968. Fish. Res. Bd., Canada, Tech. Rept. No. 122, 47 pp.

Mercer, M.C. 1970. A.T. Cameron Cruise 157, otter-trawl survey of the southwestern North Atlantic, February 1969. Fish Res. Bd., Canada, Tech. Rept. No. 199, 66 pp.

Mercer, M.C. 1970. The tropical loliginid squid Sepioteuthis sepioidea from the northwest Atlantic. J. Fish. Res. Bd., Canada, 27: 1892-1893.

Mercer, M.C. 1970. Cephalopod resources and fisheries in the northwest Atlantic. Amer. Malacol. Union Annu. Rep. Bull. 1970: 30-33.

Mercer, M.C. 1973. Observations on distribution and intraspecific variation in pigmentation patterns of odontocete Cetacea in the western North Atlantic. J. Fish. Res. Bd., Canada, 30: 1111-1130.

Mesnil, B., M.C. Mercer, and P.W. Collins. 1976. Report on R/V Cryos squid surveys, 3-19 May and 22 November - 15 December 1975. ICNAF Res. Doc. 76/87, Ser. No. 3900.

Messieh, S.N., S.N. Tibbo and L.M. Lauzier. 1971. Distribution, abundance, and growth of larval herring (Clupea harengus L.) in Bay of Fundy - Gulf of Maine area. Fish. Res. Bd., Canada, Tech Rept. No. 277, 23 pp.

Miller, D.S. 1977. ICNAF Division 5Y herring and ICNAF Division 5Z and Statistical Area 6 herring stock assessments. CAFSAC Res. Doc. 77/6.

Moores, J.A., G.H. Winters and L.S. Parsons. 1975. Migration and biological characteristics of Atlantic mackerel (Scomber scombrus) occurring in Newfoundland waters. J. Fish. Res. Bd., Canada, 32: 1347-1357.

Needler, A.W.H. 1930. Statistics of the haddock fishery in North American waters. U.S. Dept. of Commerce, Bureau of Fisheries Document No. 1074. (Also published as: Contrib. No. 2, North Am. Committee on Fishery Invest., 14 pp., King's Printer, Ottawa, 1929.)

Needler, A.W.H. 1931. The migrations of haddock and the interrelationships of haddock populations in North American waters. Contrib. Can. Biol. Fish. 6: 241-313.

Paloheimo, J.E. 1961. Studies on estimation of mortalities. I. Comparison of a method described by Beverton and Holt and a new linear formula. J. Fish. Res. Bd. Canada, 18, (5): 645-662.

Paloheimo, J.E. 1961. Estimation of mortalities of Georges Bank haddock. Fish. Res. Bd. Canada, MS Rept. Biol., No. 714, 23 pp.

Parsons, L.S. and J.A. Moores. 1973. Long distance migration of an Atlantic mackerel, Scomber scombrus, tagged in Newfoundland waters. ICNAF Res. Doc. 73/82, Ser. No. 3034.

Parsons, L.S. and J.A. Moores. 1974. Long-distance migration of an Atlantic mackerel (Scomber scombrus). J. Fish. Res. Bd., Canada, 31: 1521-1522.

Rivard, D., S. Stevenson and K. Zwanenburg. 1980. 1979 performance of commerical sampling for east coast Canadian fisheries. CAFSAC Res. Doc. 80/70.

Scattergood, L.W. and S.N. Tibbo. 1959. The herring fishery of the northwest Atlantic. Bull Fish. Res. Bd. Canada, No. 121, 42 pp.

Schnack, D. and W.T. Stobo. 1973. ICNAF Joint Larval Herring Survey in Georges Bank - Gulf of Maine areas in 1972 - preliminary summary. ICNAF Res. Doc. 73/115, Ser. No. 3081.

Scott, J.S. 1972. Morphological and meristic variation in northwest Atlantic sand launces (Ammodytes). J. Fish. Res. Bd., Canada, 29: 1673-1678.

Scott, W.B. and S.N. Tibbo. 1968. Food and feeding habits of swordfish, Xiphias gladius, in the western North Atlantic. J. Fish. Res. Bd., Canada, 25: 903-919.

Scott, W.B., A.C. Kohler and R.E. Zurbrigg. 1970. The manefish, Caristius groenlandicus Jensen (Percomorphi: Caristiidae), in Atlantic waters off Canada. J. Fish. Res. Bd. Canada, 27: 174-179.

Scott, W.B. and S.N. Tibbo. 1974. Food and feeding habits of swordfish (Xiphias gladius Linnaeus) in the northwest Atlantic Ocean. NOAA Tech. Rept. NMFS SSRF-675. In: "Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9-12 August 1972". Part 2. Review and Contributed Papers. Richard S. Shomura and Francis Williams (Editors), pp. 138-141.

Sette, O.E. and A.W.H. Needler. 1934. Statistics of the mackerel fishery off the east coast of North America, 1804 to 1930. U.S. Department of Commerce, Bureau of Fisheries. Investigational Report No. 19.

Sheldon, R.W., W.H. Sutcliffe Jr. and M.A. Paranjape. 1977. Structure of pelagic food chain and relationship between plankton and fish production. J. Fish. Res. Bd., Canada, 34: 2344-2353.

Smith, G.F.M. 1968. Status of fishery and research carried out in Subarea 5, 1967. ICNAF Res. Doc. 68/105, Ser. No. 2103. (Also published in ICNAF Annu. Proc. Vol. 18: 49-50.)

Smith, G.F.M. 1969. Status of fishery and research carried out in Subarea 5 in 1968. ICNAF Res. Doc. 69/94, Ser. No. 2274. (Also published in ICNAF Annu. Proc. Vol. 19: 46-47.)

Smith, G.F.M. 1970. Status of the fisheries and research carried out in Subarea 5 in 1969. ICNAF Res. Doc. 70/90, Ser. No. 2441. (Also published in ICNAF Annu. Proc. Vol. 20: 45-47.)

Smith, G.F.M. 1971. Status of the fisheries and research carried out in Subarea 5 in 1970. ICNAF Res. Doc. 71/129, Ser. No. 2635. (Also published in ICNAF Annu. Proc. Vol. 21: 53-55.)

Stasko, A.B. 1977. Lobster larvae on the Scotian Shelf. CAFSAC Res. Doc. 77/31.

Stasko, A.B. 1978. Inshore-offshore S.W. Nova Scotia lobster interaction: a hypothesis. CAFSAC Res. Doc. 78/37.

Stasko, A.B. 1980. Tagging and lobster movements in Canada. In: Anthony, V.C. and J.F. Caddy (ed.). Proceedings of the Canada-U.S. workshop on status of assessment science for N.W. Atlantic lobster (Homarus americanus) stocks. St. Andrews, N.B., Oct. 24-26, 1978. Can. Tech. Rept. Fish. Aquat. Sci., No. 932: 141-150.

Stasko, A.B. 1980. Lobster larval surveys in Canada. In: Anthony, V.C. and J.F. Caddy (ed.). Proceedings of the Canada-U.S. workshop on status of assessment science for N.W. Atlantic lobster (Homarus americanus) stocks. St. Andrews, N.B, Oct. 24-25, 1978. Can. Tech. Rept. Fish. Aquat. Sci. No. 932: 157-165.

Stasko, A.B. and R.W. Pye. 1980. Geographical size frequency differences in offshore lobsters. CAFSAC Res. Doc. 80/57.

Stasko, A.B. and R.W. Pye. 1980. Canadian offshore lobster fishery trends. CAFSAC Res. Doc. 80/56.

Steele, D.H. 1963. Pollock (Pollachius virens (L.)) in the Bay of Fundy. J. Fish. Res. Bd. Canada, 20: 1267-1314.

Stobo, W.T. 1976. Movements of herring tagged in the Bay of Fundy - update. ICNAF Res. Doc. 76/48, Ser. No. 3834.

Stobo, W.T. 1976. Movements of mackerel tagged in Subarea 4. ICNAF Res. Doc. 76/49, Ser. No. 3835.

Stobo, W.T., J.S. Scott, and J.J. Hunt. 1975. Movements of herring tagged in the Bay of Fundy. ICNAF Res. Doc. 75/38, Ser. No. 3517.

Stone, H. and R. Bailey. 1978. Preliminary assessment of the red crab resource off the Scotian Shelf. CAFSAC Res. Doc. 78/38.

Stone, H. and R.F.J. Bailey. 1980. A survey of the red crab resource on the continental slope, N.E. Georges Bank and western Scotian Shelf. Can. Tech. Rept. Fish. Aquat. Sci., No. 977, 9 pp.

Subba Rao, D.V. 1975. Phytoplankton production, nutrients and density structure in the shelf area of Nova Scotia and Georges Bank during August 1974. Fish. Res. Bd., Canada, Tech. Rept. No. 524, 265 pp.

Sutcliffe, W., R.H. Loucks, and K.F. Drinkwater. 1975. Consideration of coastal circulation and fish production on the Scotian Shelf and in the Gulf of Maine. ICNAF Res. Doc. 75/9, Ser. No. 3451.

Sutcliffe, W.H. Jr., R.H. Loucks and K.F. Drinkwater. 1976. Coastal circulation and physical oceanography of the Scotian Shelf and the Gulf of Maine. J. Fish. Res. Bd., Canada 33: 98-115.

Sutcliffe, W.H. Jr., K. Drinkwater and B.S. Muir. 1977. Correlations of fish catch and environmental factors in the Gulf of Maine. J. Fish. Res. Bd., Canada, 34: 19-30.

Swan, B.K. and D. Clay. 1979. Feeding study on silver hake (Merluccius bilinearis) taken from the Scotian Shelf and ICNAF Subarea 5. ICNAF Res. Doc. 79/49, Ser. No. 5388.

Taylor, C.C. and L.M. Dickie. 1958. A report on the study of the Georges Bank haddock regulation. ICNAF Res. Doc. 58/15. Ser. No. 541.

Templeman, W. 1962. Divisions of cod stocks in the Northwest Atlantic. ICNAF Redbook 1962 (III): 79-123.

Templeman, W. 1972. Year-class success in some North Atlantic stocks of cod and haddock. ICNAF Spec. Publ. No. 8: 223-238.

Tibbo, S.N., J.E.H. Legarē, L.M. Scattergood and R.F. Temple. 1958. On the occurrence and distribution of larval herring (Clupea harengus L.) in the Bay of Fundy and the Gulf of Maine. J. Fish. Res. Bd., Canada, 15: 1451-1469.

Tibbo, S.N. and J.E.H. Legarē. 1960. Further study of larval herring (Clupea harengus L.) in the Bay of Fundy and Gulf of Maine. J. Fish. Res. Bd. Canada, 17: 933-942.

Tibbo, S.N., L.R. Day and W.F. Doucet. 1961. The swordfish (Xiphias gladius L.), its life-history and economic importance in the northwest Atlantic. Bull. Fish. Res. Bd. Canada, No. 130, 47 pp.

Tibbo, S.N. 1962. New records of occurrence of the white-tip shark, Pterolamiops longimanus (Poey), and the dolphin, Coryphaena hippurus L., in the Northwest Atlantic. J. Fish. Res. Bd. Canada, 19: 517-518.

Tibbo, S.N. and R.A. McKenzie. 1963. An occurrence of dusky sharks, Carcharhinus obscurus, (Lesueur) 1818, in the Northwest Atlantic. J. Fish. Res. Bd. Canada, 20: 1101-1102 + 1 plate.

Tibbo, S.N. 1964. Review of Canadian fishery and research on large pelagic fish in the ICNAF Area in 1963. ICNAF Res. Doc. 64/74, Ser. No. 1370.

Tibbo, S.N., L.M. Lauzier, and A.C. Kohler. 1965. Canadian fisheries research extends to the Caribbean Sea. Trade News 17 (11-12): 3-9.

Tibbo, S.N. and L.M. Lauzier. 1969. On the origin and distribution of larval swordfish Xiphias gladius L. in the western Atlantic. Fish. Res. Bd., Canada, Tech. Rept. No. 136, 20 pp.

Tibbo, S.N. and L.M. Lauzier. 1970. Larval swordfish (Xiphias gladius) from three localities in the western Atlantic. J. Fish. Res. Bd., Canada, 26: 3248-3251.

Tibbo, S.N. and L.M. Lauzier. 1970. Seasonal distribution of larval herring in the Bay of Fundy and Gulf of Maine. ICNAF Res. Doc. 70/52, Ser. No. 2388.

Tibbo, S.N., and A. Sreedharan. 1972. The Canadian swordfish fishery. Abstract in NOAA Tech. Rept. NMFS SSRF-675, July 1974.

Trites, R.W. 1978. Some physical oceanographic features relevant to larval herring distribution on Georges Bank. ICNAF Res. Doc. 78/79. Ser. No. 5266.

Wilder, D.G. and D.E. Graham. 1973. Offshore lobster trap fishing July 10 to August 10, 1972. Fish. Res. Bd. Canada, Man. Rept., No. 1236, 24 pp.

Winters, G.H. 1978. Estimation of natural and total mortality rates of northwest Atlantic mackerel. CAFSAC Res. Doc. 78/35.

Wilson, A.J. and D.G. Wilder. 1967. Lobster trap fishing on Georges Bank and Seal Island grounds August 14 to September 20, 1967. Fish. Res. Bd. Canada, Man. Rept. No. 948, 15 pp.

Wilson, P.C. and J.S. Beckett. 1970. Atlantic Ocean distribution of the pelagic stingray, Dasyatis violacea. Copeia, 1970, No. 4: 696-707.

APPENDIX 2: RECORD OF CANADIAN FISHERIES RESEARCH VESSEL ACTIVITY IN NAFO SUBAREAS 5 AND 6 (INCLUDING CHARTERS).

(BT = bottom trawl, MWT = midwater trawl, LL = longline, HL = handline, DGN = drift gillnet)

Dates	Vessel	Cruise No.	Purpose	Operation Data
Summer 1953	Point Pleasant	...	Herring exploratory fishing. Dutch herring trawl.	SA4, 5Z (15 tows in 5Z)
20-21 Jul 1955	Harengus	...	Herring exploratory fishing. Drift nets.	5Z
30 Aug-14 Sept 1955	Harengus	...	Herring exploratory fishing. Dutch herring trawl.	5Z
Sept, Oct, Nov, 1956	Harengus	...	Herring: larval survey	4X, 5Y
Sept, Oct, Nov, 1957	Harengus	...	Herring: larval survey	4X, 5Y
Feb 1958	Fort Francis	...	Herring: larval survey	4X, 5Y
7-8 Oct 1958	Harengus	HS-24	Herring: larval survey	5Z
15-30 Oct 1958	Harengus	HS-25	Herring: larval survey	4X, 5Y, 5Z
10-24 Nov 1958	Harengus	HS-27	Herring: larval survey	4X, 5Y, 5Z
16-31 Jan 1959	A.T. Cameron	ATC-03	Herring: plankton and sonar survey. Trawling on N. Georges	4X, 5Y, 5Z
5-11 Nov 1959	Sackville(?)	S-47	Herring: larval survey	4X, 5Y, 5Z
30 Aug-9 Sept 1961	Cape Eagle	CE-1	Scallops: gear efficiency distribution	5Z
4-14 Oct 1961	A.T. Cameron	ATC-46	Pelagics: B&MW trawls, LL, DGN, hydrography	4X, 5Z
17-28 Oct 1961	A.T. Cameron	ATC-47	Pelagics: B&MW trawls, LL, HL, hydrography, plankton	4X, 5Z
23-31 Jul 1962	Harengus	H-39	Pelagics: LL, GN, hydrography, tagging	4X, 5Z
3-9 Aug 1962	Harengus	H-40	Pelagics: LL, BT, hydrography, tagging	4X, 5Z
8-18 Sept 1962	A.T. Cameron	ATC-59	Pelagics: BT, LL, plankton, hydrography	4X, 5Z

18-28 Sept 1962	A.T. Cameron	ATC-60	Pelagics: BT, LL, HL, hydrography	4X, 5Z
16-27 Aug 1963	A.T. Cameron	ATC-75	Scallops: comparative gear efficiency, photography & survey. Herring: survey	5Z
25 Feb-4 Mar 1964	A.T. Cameron	ATC-83	Groundfish: Vertical dist. studies by trawling, sounder and photography	4X, 5Z
3-15 Aug 1964	A.T. Cameron	ATC-90	Pelagics: LL for large pelagics. Trawling for herring	5Z
18-27 Aug 1964	A.T. Cameron	ATC-91	Scallops: survey	5Z
6-15 Oct 1964	Alder Point	AP-2	Large Pelagics: LL, biological parameters	5Z
17-26 Jul 1965	Louise P.	LP-01	Exploratory fishing for lobsters, argentine, silver hake and herring: BT	5Z (51 sets)
11-20 Aug 1965	Louise P.	LP-03	As for LP-01	5Z (64 sets)
25 Sept-7 Oct 1965	A.T. Cameron	ATC-107	Large pelagics: LL. Herring: B. and Dutch herring trawls. Plankton and hydrography	5Z (7 LL sets) (16 trawl sets)
18-30 July 1966	P.J. Lawrence	L-03	Exploratory fishing for lobsters and red crabs, argentine, silver hake, and herring	4WX, 5Z (19 of 65 stns in 5Z)
3-8 Aug 1966	Harengus	H-88	Scallop survey	5Z (31 stns)
18-28 Aug 1966	A.T. Cameron	ATC-121	Large pelagics: LL Herring: trawling Plankton, hydrography	4VWX, 5Z (4 of 15 stns in 5Z)
2-14 Feb 1967	A.T. Cameron	ATC-128	Plankton, hydrography, Herring: trawling on N. Georges	4X, 5Z
16 Mar-10 Apr 1967	A.T. Cameron	ATC-130	Squid (Illex): distribution abundance, biology. BT (39 sets), misc. other gears (33 sets)	4X, 5Z, SA6
3-21 Apr 1967	E.E. Prince	P-03	Large pelagics: survey and tagging, LL., sonar. Plankton hydrography	SA6

24 Apr-3 May 1967	E.E. Prince	P-04	Ichthyoplankton and hydrography	4X, 5Y (5Z-not sampled due to weather)
4-12 Jul 1967	P.J. Lawrence	L-5	Groundfish survey: silver hake, argentine, sand launce	4X, 5Y, 5Z
27 Jul-4 Aug 1967	E.E. Prince	P-10	Ichthyoplankton and hydrography	4X, 5Y, 5Z
Aug-Sept 1967	Albert Riske	AR-1	Exploratory fishing for lobster on Georges Bank using traps	4X, 5Z (620 trap hauls in 5Z)
7-15 Nov 1967	E.E. Prince	P-15	Ichthyoplankton and hydrography	4X, 5Y, 5Z
18-24 Jan 1968	Kapuskasing	KAP-05	Ichthyoplankton and hydrography	4X, 5Y, 5Z
4-12 Apr 1968	E.E. Prince	P-24	Ichthyoplankton and hydrography	4X, 5Y, 5Z
3-14 Jul 1968	E.E. Prince	P-30	Groundfish survey	4X, 5Z (69 sets total)
3-12 Jul 1968	Harengus	H-96	Swordfish and shark tagging LL, BT, harpoon	4W, 5Z
17-25 Jul 1968	E.E. Prince	P-31	Ichthyoplankton and hydrography	4X, 5Y, 5Z (93 stns total)
20-28 Jul 1968	Harengus	H-105	Large pelagics: tagging and sampling for mercury	5Z
23 Jul-6 Aug 1968	Promise	PR-01	Swordfish tagging: harpoon	4W, 4X, 5Z
15 Aug-3 Sept 1968	A.T. Cameron	ATC-150	Squid (Illex): distribution abundance, biology. BT (67 sets) misc. other gear (45 sets)	SA3, SA4 5Zw, 6 and south
Sept 1968	Theta	...	Ichthyoplankton gear experiments	5Z
6-12 Nov 1968	E.E. Prince	P-37	Herring acoustic survey	5Y
19-26 Nov 1968	E.E. Prince	P-38	Ichthyoplankton and hydrography	4X, 5Y, 5Z (89 stns total)
21-28 Jan 1969	Chebucto	CH-01	Ichthyoplankton and hydrography	4X, 5Y, 5Z (88 stns total)

9 Feb-5 Mar 1969	A.T. Cameron	ATC-157	Squid (Illex): distribution abundance, biology. BT, plankton, hydrography	SA6 and south (53 stns)
25 Apr-22 May 1969	Sackville	BIO-69-023	Large Pelagics: LL, biological parameters, hydrography plankton	SA6 and south
29 Apr-4 May 1969	E.E. Prince	P-44	Ichthyoplankton and hydrography	4X, 5Y (93 stns total)
21-29 Jul 1969	E.E. Prince	P-50	Ichthyoplankton and hydrography	4X, 5Y (95 stns total)
14-18 Oct 1969	E.E. Prince Chebucto	P-56 CH-03	Ichthyoplankton and hydrography	4X, 5Y (95 stns total)
12-17 Nov 1969	E.E. Prince	P-58	Herring: larval and adult sampling.	4X, (Aimed at 5Z but weather prevented off-shore operations)
17-23 Apr 1970	E.E. Prince	P-69	Ichthyoplankton and hydrography	4X, 5Y, 5Z (87 stns total)
4-15 Jun 1970	E.E. Prince	P-72	Scallops: survey, dredge selection, photography	5Z
20-28 Jul 1970	Promise	...	Swordfish: tagging	4X, 5Z
10-14 Aug 1970	Chebucto	CH-04	Ichthyoplankton and hydrography	4X, 5Y, 5Z (67 stns total)
1-8 Jun 1971	E.E. Prince	P-86	Scallops: gear selectivity and survey	5Z
20-28 July 1971	Harengus	H-104	Large Pelagics: LL, mercury contamination	5Z
12-20 Oct 1971	Dorothy & Gail	DG-3	Large Pelagics: LL, hydrography, plankton, mercury contamination	5Z, 6
26 May-7 June 1972	Francis Geraldine	FG-6	Large Pelagics: LL, hydrography, mercury contamination	4V, 6
8-14 Jun 1972	E.E. Prince	P-101	Scallops: gear selectivity	5Z
13-28 Jun 1972	Francis Geraldine	FG-7	Large Pelagics: LL, hydrography, mercury contamination	4X, 5Z, 6
19-25 Jul 1972	Harengus	...	Tuna tagging	SA6

8-15 Jun 1973	E.E. Prince	P-118	Scallops: survey and gear trials	5Z (61 stns)
2-17 Aug 1973	E.E. Prince	P-120	Bluefin tuna: tagging and sonar survey	SA6
5-14 Aug 1975	Dorothy & Gail	...	Large Pelagics: LL, hydrography, tagging mercury contamination	4X, 5Z
5-14 Aug 1975	Scotian Maid	...	Large Pelagics: LL, hydrography, tagging mercury contamination	4X, 5Z
17 Nov-19 Dec 1976	Cape Argos	CA-01,02,03	Mackerel: offshore winter distributional survey	4VWX, 5Z
21-31 Mar 1977	A.T. Cameron	ATC-259	Groundfish survey	4W, 4X, 5Z (8 sets in 5Z)
6-21 Jul 1977	E.E. Prince	P-185	Scallops: survey and tagging	5Z (148 stns)
15-24 Nov 1977	E.E. Prince	P-191	Herring: larval patch study	5Z
6-11 Apr 1978	E.E. Prince	P-194	Haddock parasite studies	4WX, 5Z (9 stns in 5Z)
30 May-10 Jun 1978	E.E. Prince	P-199	Scallops: evaluate search methods and tagging	5Z (160 stns)
7-28 Jul 1978	E.E. Prince	P-201	Scallops: survey and tagging	5Z (94 stns)
12-15 Jul 1978	Adventure	...	Lobster: larval survey	4X, 5Z (12 stns in 5Z)
9 Aug-8 Sept 1978	Lady Hammond	H-05, 06, 07	Scotian Shelf Icthyoplankton Programme	4VWX, 5Z (15 stns in 5Z)
11 Sept-11 Oct 1978	Judy and Linda IV	...	Exploratory fishing for red crab	4WX, 5Z (2 of 9 transects in 5Z)
16 Oct-10 Nov 1978	Lady Hammond	H-08	Herring: larval patch study	5Z
23 Oct-10 Nov 1978	Canso Condor	CC-03	Herring: patch study, egg predation study, plankton study, feeding study. BT, MWT, plankton nets.	5Z (49 BT, 29 MWT)
21-31 Mar 1979	A.T. Cameron	ATC-288	Groundfish survey	4W, 4X, 5Z (8 sets in 5Z)
1-25 Apr 1979	Lady Hammond	H-15	Scotian Shelf Ichthyoplankton Programme	4VWX, 5Z (7 stns in 5Z)

June 1979	E.E. Prince	P-220	Scallop survey	5Z
12 Nov-5 Dec 1979	Lady Hammond	H-28	Scotian Shelf Ichthyoplankton Programme	4VWX, 5Z (5 stns in 5Z)
5-27 Feb 1980	Lady Hammond	H-32	Scotian Shelf Ichthyoplankton Programme	4VWX, 5Z (4 stns in 5Z)
17-27 Mar 1980	Lady Hammond	H-34	Groundfish survey	4WX, 5Z (8 sets in 5Z)
6-30 May 1980	Lady Hammond	H-35	Scotian Shelf Ichthyoplankton Programme	4VWX, 5Z (6 stns in 5Z)
13-31 May 1980	E.E. Prince	P-237	Scallops: survey and tagging	5Z (180 stns)
2-26 Jun 1980	Lady Hammond	H-36	Scotian Shelf Ichthyoplankton Programme	4VWX, 5Z (7 stns in 5Z)
28-31 Jul 1980	E.E. Prince	P-241	Scallops: BRUTIV survey trials	5Z
4-18 Aug 1980	Jane R.	JR-01	Swordfish: biological studies	5Z, SA6
29 Sept-8 Oct 1980	Jane R.	JR-04	Swordfish: biological studies	5Z

APPENDIX 3: RECORD OF CANADIAN FISHERIES RESEARCH VESSEL ACTIVITY SOUTH OF NAFO SUBAREA 6

(LL = longline, MWT = midwater trawl)

Dates	Vessel	Cruise No.	Purpose	Operational data
1-27 Feb 1965	Hudson	BIO-3-65	Large Pelagics: biological parameters, hydrography plankton, LL.	Cape Hatteras to Caribbean
20 Jan-12 Feb 1966	A.T. Cameron	ATC-111	Large Pelagics: biological parameters, hydrography plankton, LL, MWT.	Cape Hatteras to Florida Keys
22 Mar-2 Apr 1968	Hudson	...	Large Pelagics: biological parameters, hydrography, plankton.	Caribbean
6 Jan-15 Feb 1969	Sackville	BIO-69-003	Large Pelagics: biological parameters, hydrography, plankton, LL.	Bermuda to Caribbean
10 Feb-17 Mar 1970	Sackville	BI-70-004	Large Pelagics: LL, biological parameters, hydrography, plankton, bottom dredge.	Caribbean Sea and Gulf Stream to 35°N
21 Feb-25 Mar 1972	Dawson	72-004	Large Pelagics: LL, biological parameters, hydrography, plankton.	Caribbean Sea and Gulf Stream to 35°N

APPENDIX 4: RECORD OF CANADIAN OBSERVERS ABOARD DOMESTIC COMMERCIAL FISHING VESSELS FOR THE PURPOSE OF COLLECTING BIOLOGICAL DATA - NAFO SUBAREAS 5 and 6

Dates	Vessel (Cruise No.)	Area	Fishing For:	Gear	Scientific data
Aug and Oct 1958	...	5Z	Scallops	Drag	Quantities and sizes discarded
19 Jun-6 Jul 1959	Pubnico Pal	5Z	Swordfish	Harpoon	Distribution, parasites, food, behaviour, hydrography
June and Aug 1959	...	5Z	Scallops	Drag	Biological sampling and catch rates
Oct and Nov 1959	Aegir	5Z	Scallops	Drag	Gear selection trials and biological sampling
June 1962	Michael R	5Z	Scallops	Drag	Biological sampling and catch rates
26 Jul-4 Aug 1962	Judith Irene (62-2)	5Z	Scallops	Drag	Biological sampling and catch rates
16-25 Apr 1963	Blue Dawn (63-1)	5Z	Scallops	Drag	Biological sampling and catch rates
15-27 Jun 1963	Beiner (B-1)	4X, 5Z	Swordfish	Longline	Distribution, food, hydrography
24 Jun-5 Jul 1963	Elizabeth Ann (63-2)	5Z	Scallops	Drag	Biological sampling and catch rates
4-17 Jul 1963	Beiner (B-2)	4W, 4X, 5Z	Swordfish	Longline	Distribution, food, hydrography
Aug 1963	Shirley & Joyce	5Z	Scallop	Drag	Gear operations
5 Feb-27 Mar 1964	Beiner (B-3)	5A6	Swordfish	Longline	Biological parameters, hydrography
17-26 Jun 1964	Blue Dawn (64-1)	5Z	Scallop	Drag	Biological sampling hydrography
8-18 Jul 1964	Commodore (C-4)	4X, 5Z	Swordfish	Longline	Biological parameters, hydrography
3-20 Sept 1964	Bluewaters	5Z, 6A	Tuna	Purse seine	Biological sampling and catch rates
22 May-1 Jun 1965	Francis Geraldine (FG-1)	5A6	Swordfish	Longline	Biological parameters, hydrography
12-29 Jun 1965	Bluewaters	5Z, 6A	Tuna	Purse seine	Biological sampling and catch rates
Jul/Aug 1965	Bluewaters	5Z, 6A	Tuna	Purse seine	Biological sampling and catch rates
Jul/Aug 1965	Greenwaters	5Z, 6A	Tuna	Purse seine	Biological sampling and catch rates
9-20 Jun 1965	Francis Geraldine (FG-2)	5A6	Swordfish	Longline	Biological parameters, hydrography

2-16 Jul 1965	Beiner (B-4)	4X, 5Z	Swordfish	Longline	Biological parameters, hydrography
31 May-10 Jun 1966	Francis Geraldine (FG-3)	4WX, 5Z	Swordfish	Longline	Biological parameters hydrography
29 Jun-12 Jul 1966	Judith R. (JR-1)	4WX, 5Z	Swordfish	Longline	Biological parameters, hydrography
25 Jul-1 Aug 1966	Greenwaters	SA6	Tuna	Purse seine	Biological parameters
12-21 Jun 1967	Francis Geraldine (FG-4)	4X, 5Z	Swordfish	Longline	Biological parameters, tagging, hydrography
5-16 Jun 1968	Judith R. (JR-3)	5Z	Swordfish	Longline	Hydrography
17 Nov-2 Dec 1969	Jane R. (JR-4)	SA6	Swordfish	Longline	Biological parameters, hydrography
23 Jul-7 Aug 1971	Atl. Gairdner	SA6	Bluefin tuna	Purse seine	Biological parameters and tagging
31 Jul-5 Aug 1971	Atl. JAG	SA6	Bluefin tuna	Purse seine	Biological parameters and tagging
29 Jun-7 Jul 1977	Cape LaHave	5Z, 4X	Groundfish	Bottom trawl	Biological samples of catch
8-16 Jun 1977	Cape Hunter	5Z, 4X	Groundfish	Bottom trawl	Biological samples of catch
28 Sept-7 Oct 1977	Lady Yvette	5Z	Scallops	Drag	Comparison of 3" and 4" rings
30 Sept-14 Oct 1977	Kay Angela	5Z	Scallops	Drag	Comparison of 3" and 4" rings
18 Feb-1 Mar 1978	Cape Bauld	4X, 4W, 5Z	Groundfish	Bottom trawl	Biological samples of catch
20 Feb-1 Mar 1978	Cape John	4X, 5Z	Groundfish	Bottom trawl	Biological samples of catch
25 May-5 Jun 1978	Ester Boyd	5Z, 4X	Groundfish	Bottom trawl	Biological samples of catch
29 May-4 June 1978	Cape Nelson	4X, 5Z	Groundfish	Bottom trawl	
1-12 Jun 1978	Cape John	5Z	Groundfish	Bottom trawl	Biological samples of catch
1-10 June 1978	Cape LaHave	5Z	Groundfish	Bottom trawl	Biological samples of catch
21 June-7 Jul 1978	Cape York	5Z, 4X	Groundfish	Bottom trawl	Biological samples of catch
27 Jun-7 Jul 1978	W.R. Ritcey	5Z, 4W	Groundfish	Bottom trawl	Biological samples of catch
28 Jun-8 Jul 1978	Cape Nova	5Z, 4X	Groundfish	Bottom trawl	Biological samples of catch
5-15 Jul 1978	Cape Charles	4X, 5Z	Groundfish	Bottom trawl	Biological samples of catch
17-20 Sept 1978	Vicki Brothers	5Z	Groundfish	Bottom trawl	Biological samples of catch

9-16 Oct 1978	Cape Hunter	5Z	Groundfish	Bottom trawl	Biological samples of catch
16-23 Oct 1978	Hillsborough	5Z	Groundfish	Bottom trawl	Biological samples of catch
8-18 Nov 1978	Cape York	5Z	Groundfish	Bottom trawl	Biological samples of catch
20 Feb-3 Mar 1979	Primo	5Z	Scallops	Drag	Stratified sampling and freshwater uptake of iced meats
12-23 Jun 1979	LP MacDonald	5Z	Scallops	Drag	Stratified sampling and freshwater uptake of iced meats
13-23 Feb 1980	Cape John	4W, 4X, 5Z	Groundfish	Bottom trawl	
16-28 Feb 1980	Cape Howe	4W, 4RS 4XN, 5Z	Groundfish	Bottom trawl	Biological samples of catch
21 Feb-1 Mar 1980	Cape Hunter	3Ps, 4Vs 4W, 5Z	Groundfish	Bottom trawl	Biological samples of catch
14-26 May 1980	Cape Hood	5Z, 4X, 4W	Groundfish	Bottom trawl	Biological samples of catch
16-23 Jun 1980	Canso Condor	5Z, 4X	Groundfish	Bottom trawl	Biological samples of catch
27 Sept-6 Oct 1980	Hillsborough	4X, 5Z	Groundfish	Bottom trawl	Biological samples of catch
27 Sept-6 Oct 1980	Cape LaHave	5Z	Groundfish	Bottom trawl	Biological samples of catch
29 Nov-10 Dec 1980	Cape York	4X, 5Z	Groundfish	Bottom trawl	
5-11 Dec 1980	Bedeque	4X, 5Z	Groundfish	Bottom trawl	Biological samples of catch
9-19 Dec 1980	Cape Wrath	4W, 5Z	Groundfish	Bottom trawl	

APPENDIX 5: RECORD OF PHYSICAL OCEANOGRAPHIC OBSERVATIONS MADE FROM CANADIAN VESSELS IN SUBAREA 5.

Table 1. Chronological listing of cruises which undertook oceanographic measurements within NAFO Subarea 5 during at least some portion of the cruise. If both temperature and salinity were measured they are listed under "Oceanographic Stations". A listing for Bathythermographs is shown separately.

Year	No. of cruises	Oceanographic Stns.	Bathythermographs
1929	3	11	
1930	1	5	
1932	1	23	
1943	1		5
1945	1		1
1946	3		17
1947	13		59
1948	3		8
1949	2		33
1950	5	36	38
1951	6	8	8
1952	10	41	28
1953	4	7	6
1954	8	12	40
1955	6	12	24
1956	7		77
1957	5	12	81
1958	7	68	97
1959	2	53	47
1960	6	16	23
1961	10	64	38
1962	9	70	47
1963	11	42	26
1964	6	97	96
1965	6	121	115
1966	8	21	91
1967	4	137	50
1968	9	136	144
1969	10	99	61
1970	12	66	78
1971	11	39	44
1972	11	30	62
1973	7	45	56
1974	6	38	34
1975	6	38	34
1976	3	22	40
1977	10	245	135
1978	12	618	197
1979	10	84	28
1980	8	102	

Table 2. Chronological listing of surface and/or seabed drifter releases made within NAFO Subarea 5. The number of subsequent recoveries is also listed.

Year	Number of Drifter Releases	No. of Subsequent Recoveries
1957	45	4
1958	312	111
1960	1165	93
1961	2453	231
1962	1865	85
1963	1865	165
1964	904	376
1965	2352	539
1966	1144	122
1967	3181	420
1968	2343	357
1969	2351	347
1970	2243	438
1971	134	8
1972	750	172
1973	1241	96
1974	272	0
1979	480	10
1980	110	6